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ABSTRACT

This packet of instructional materials for a gas tungsten arc welding (GTAW) and plasma arc cutting course is comprised of a teacher edition, student edition, and student workbook. The teacher edition consists of introductory pages and teacher pages. Introductory pages include training and competency profile, state duty/task crosswalk, instructional/task analysis, basic skills icons and classifications, basic skills matrix, and tools, equipment, and materials list. Teacher pages provide some or all of these components for each of the three units: unit contents, suggested activities, answers to assignment sheets, written test, answers to written test, teacher supplements, and transparency masters. The student edition consists of some or all of these components for each unit: unit contents, learning activities sheet, objective sheet, information sheet, and student supplements. The student workbook contains the pen-and-pencil exercises and skills tests necessary for student mastery of the course, including some or all of these components: workbook contents, assignment sheets, and job sheets. The three units of instruction are GTAW orientation and safety; GTAW equipment, applications, and techniques; and plasma arc cutting. (YLB)

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ED 456 331

Gas Tungsten Arc Welding and Plasma Arc Cutting

Second Edition

- **Teacher Edition**
- **Student Edition**
- **Student Workbook**

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Gas Tungsten Arc Welding and Plasma Arc Cutting

SECOND EDITION

MAVCC

Teacher Edition

02-15268

Gas Tungsten Arc Welding and Plasma Arc Cutting

Second Edition

Teacher Edition

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Unit 2: GTAW Equipment, Applications, and Techniques

Unit 3: Plasma Arc Cutting

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Foreword

Gas Tungsten Arc Welding and Plasma Arc Cutting, Second Edition retains a substantial amount of the first edition of this publication. The care and feeding of tungsten electrodes and the entire concept of contamination control are treated in detail in the GTAW section of this text. The Plasma Arc Cutting section introduces the hafnium electrode and its importance in dual-air cutting systems that use compressed shop air for PAC activities. The text is state-of-the-art, and will be a valuable addition to any welding program.

These instructional materials have been designed to assist teachers in improving instruction. Every effort has been made to make these materials basic, readable, and usable. The teacher will need to develop instructional strategies for motivating their students, and localizing, individualizing, and supplementing the instructional materials. Suggestions for teaching the unit, suggested supplemental resources including Internet resources, a criterion-referenced test, and transparency masters are included in the teacher pages for each unit of instruction.

This edition of *Gas Tungsten Arc Welding and Plasma Arc Cutting* includes a student workbook that contains an assignment sheet for Unit 1 and job sheets for Unit 2 and Unit 3. Student workbooks can be purchased individually each year to provide new students with the assignment and job sheets needed to master the course.

MAVCC's welding series is crosswalked to the state of Oklahoma's welding duty/task list which is aligned to AWS standards.

Mervin Birdwell, Chair
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Multistate Academic and
Vocational Curriculum
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Consortium

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Appreciation is also extended to Rick Lomenick and to the Art Department for creating artwork and to the employees of the Graphics Division of the Oklahoma Department of Career and Technology Education for printing this publication.

Thanks are also extended to Jane Huston, MAVCC Director of Development.

Use of This Publication

Gas Tungsten Arc Welding and Plasma Arc Cutting is available in both a teacher and student edition. The contents of these materials are tied to measurable and observable learning outcomes that were identified and validated by the welding advisory committee, comprised of business/industry representatives and teachers. Competencies align with the welding duty/task list developed by the state of Oklahoma.

Teacher Edition

The teacher edition consists of introductory pages and teacher pages. It is recommended that the instructor purchase the student edition and student workbook for a complete teacher edition. The introductory and teacher pages are loose-leaf and three-hole punched. The student edition is spiral-bound, and the student workbook is perfect-bound with the pages perforated for easy removal. Each are divided into units of instruction that may be broken into more than one lesson or class period. For added flexibility, each unit in the teacher edition is individually numbered beginning with a T for teacher page, followed by the unit number and page number.

Examples:

Page 17 of Unit 3 in the teacher pages is represented as T 3–17.

MAVCC—*Gas Tungsten Arc Welding and Plasma Arc Cutting* T 3–17

Pages in the student workbook are numbered sequentially beginning with page 1.

MAVCC—*Gas Tungsten Arc Welding and Plasma Arc Cutting* Page 1

Page 7 of Unit 5 in the student edition is represented as Page 5–7.

MAVCC—*Gas Tungsten Arc Welding and Plasma Arc Cutting* Page 5–7

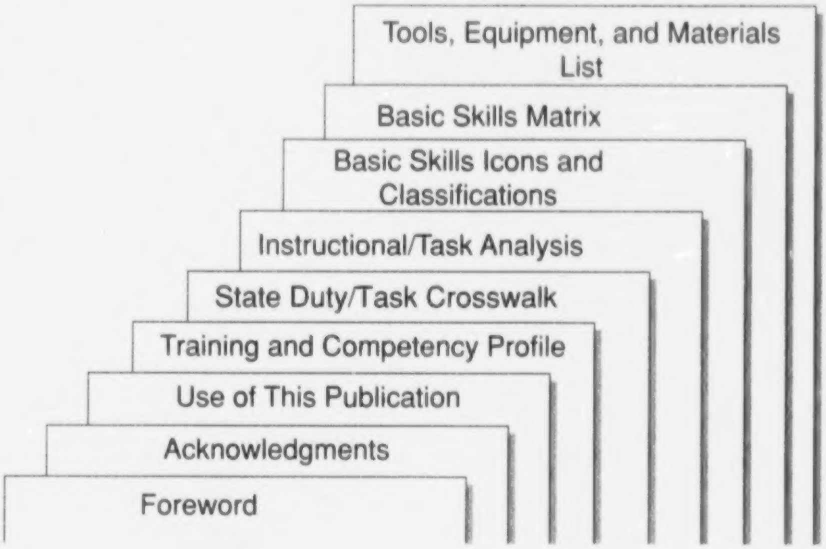
Use of This Publication

For group instruction, the teacher should determine the best way to teach each objective and allow for student participation. For self-paced or individualized instruction, students should be provided with opportunities to become involved in planning and being responsible for their own education. Careful study of each unit of instruction by the teacher will help to determine the following:

- amount of material that can be covered in each class period;
- supplies and materials required for assignment sheets and job sheets;
- resource people who must be contacted;
- supplementary materials to be ordered;
- skills that must be demonstrated and the amount of class time needed for demonstrations; and
- amount of class time needed for student practice and return demonstrations of mastered skills.

Teachers are encouraged to localize and personalize these materials to meet the needs of individual students, the community, and prospective employers.

Introductory Pages


Tools, Equipment, and Materials List
Basic Skills Matrix
Basic Skills Icons and Classifications
Instructional/Task Analysis
State Duty/Task Crosswalk
Training and Competency Profile
Use of This Publication
Acknowledgments
Foreword

Use of This Publication

In addition to general information, such as the table of contents, acknowledgments, and the use of this publication, the following tools have been provided to assist administrators and teachers in planning for instruction.

☐ **Training and Competency Profile.** This form may be copied and used to record information about each student, such as enrollment dates, class attendance, and work experience, and to document the student's mastery of specific job competencies. It can also be used to provide information about the student's qualifications to potential employers and/or for entry into advanced training programs.

☐ **State Duty/Task Crosswalk.** This document identifies the state skill standards covered in this publication and lists specifically where these skills are located by unit number and objective or assignment and/or job sheet.

☐ **Instructional/Task Analysis.** This document provides a quick review of the contents of this publication by identifying the cognitive skills (what the student should know) and psychomotor skills (what the student should be able to do) addressed in each unit of instruction.

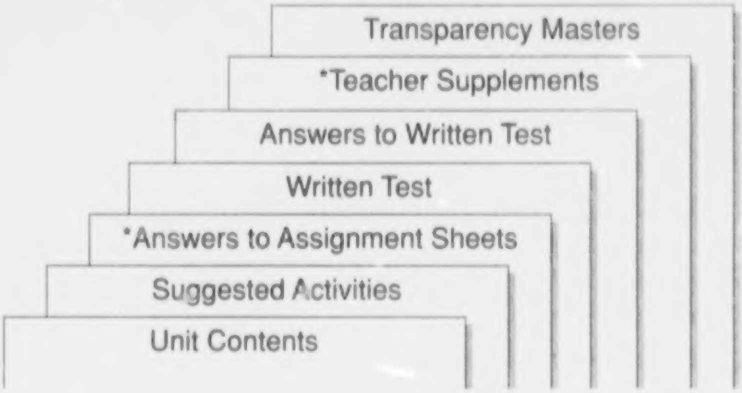
☐ **Basic Skills Icons and Classifications.** This page provides a reference guide of the graphic symbols that are used to identify the basic academic and workplace skills included in each assignment sheet and job sheet.

☐ **Basic Skills Matrix.** This document graphically summarizes the academic and workplace skills training included in the instructional materials, unit by unit. It should be helpful to teachers in planning for instruction, and to administrators as documentation that basic skills are being taught as part of the vocational training.

☐ **Tools, Equipment, and Materials List.** This document provides a comprehensive list of those items needed in a vocational program for students to complete training. It also can assist administrators and teachers in determining program costs.

Use of This Publication

Teacher Pages



*Designates components that may not appear in every unit of instruction

Teachers should study the teacher and student pages before introducing the unit, allowing enough time to obtain supplemental materials and to contact outside resource persons.

☐ **Suggested Activities.** This component assists teachers during the preparation stage of the teaching/learning process by providing an instructional plan, teaching suggestions, a list of references used in the development of each unit, and a list of suggested supplemental resources (books, posters, pamphlets, videotapes, computer software, and Internet sites) that may be used to enhance instruction.

Instructions for evaluating student performance on the assignment sheets and job sheets are also included in the suggested activities section. Teachers should select and discuss with students the rating scale that will be used.

☐ **Answers to Assignment Sheets.** An answer key is provided, when applicable, to assist the teacher in evaluating student performance on a given assignment.

☐ **Written Test.** This component provides criterion-referenced evaluation of every cognitive objective listed in the unit of instruction, and serves as both a pretest and posttest to assist teachers in measuring each student's competency gains. (Assignment sheet and job sheet objectives are not evaluated on the written test.) If the teacher has added, deleted, or modified any objectives, appropriate changes should be made to both the test and answers to the written test.

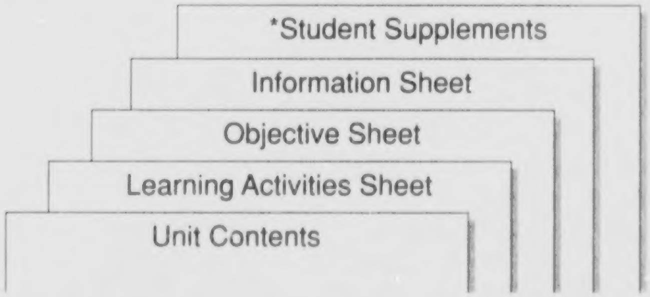
Tests may be divided into shorter tests covering three or four objectives at a time and given soon after those objectives have been covered. A selection of test items from the units covered may be used for a final test at the end of each term if desired. The written test is included in the teacher edition only and should be duplicated for student use.

☐ **Answers to Written Test.** An answer key is provided to assist the teacher in evaluating student performance on the written test.

☐ **Teacher Supplements.** These are optional materials for the teacher to use. They have three purposes: to provide the teacher with higher-level materials to stretch the advanced student; with remedial information or practice to assist the less-advanced student; and with state-of-the-art information in which the teacher may not have a background or with information that is not readily available in other books. Some teacher supplements may be duplicated for student use and are marked accordingly.

☐ **Transparency Masters.** These overheads are used to direct the students' attention to the topic of classroom discussion. Transparencies allow the student to see as well as hear the information being presented, thus reinforcing the learning process. They may provide illustrations, charts, schematics, or additional information needed to clarify and reinforce objectives included in the unit of instruction. Some of these items may also appear with the appropriate objectives in the information sheet in the student edition. The teacher may make acetate copies from the masters or, in most cases, complete transparency sets are available for purchase.

Student Edition



*Designates components that may not appear in every unit of instruction

For best results, students should be provided with a copy of the student edition and should be allowed to take notes in the margins as additional information is provided by the instructor or as the student acquires additional information through library or Internet research.

Use of This Publication

☐ **Learning Activities Sheet.** This component can be used to guide the student in self-paced or individualized programs, and in other programs provides the student with an overview of how components interface within the unit. It's designed to guide the student through the required and optional components in the student edition (objective sheet, information sheet, student supplements) and through the assignment sheets and job sheets located in the student workbook. The teacher is encouraged to use this component as a model and modify the learning steps as needed to incorporate resources available in the classroom (videotapes, computer software, magazines, etc.) and to address instructional strategies that may be needed to enhance learning for each student.

The following icons will be used on the learning activities sheet to denote steps that require additional resources:

📖 Read a book, magazine, or journal article

💻 Use a CBT program or other software application

WWW Access a site on the World Wide Web

🖥 Look at PowerPoint® or other computer presentation

📼 Watch a videotape

☐ **Objective Sheet.** This component summarizes each unit for the student and teacher. The objective sheet is based on established performance objectives that state the goals for successful completion of a unit of instruction. Objectives are stated in two forms: unit objectives that state the expected performance of each student after completion of the unit and specific (enabling) objectives that state what the student must be able to do to reach the unit objective.

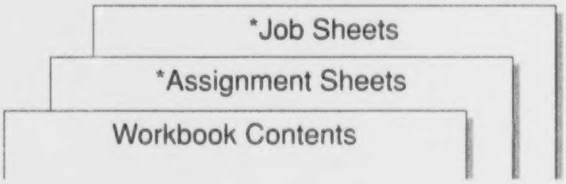
The objectives should be stressed throughout the teaching/learning process. This will help answer any questions concerning performance requirements for each instructional unit. The objectives can also help determine teaching strategies and instructional methods.

Teachers should modify, delete, or add objectives in order to meet the needs of the students and community. When objectives are added, the teacher should remember to supply the needed information, assignment and/or job sheets, and criterion-referenced test items to cover the new objectives.

☐ **Information Sheet.** This component provides the student with the essential information for meeting the cognitive objectives in the unit. Teachers will find that the information sheet serves as an excellent guide for presenting background knowledge necessary to develop the skills specified in the unit objective. Students should read the information sheet before the information is discussed in class. Space is provided in the margins for students and teachers to add notes that clarify and/or expand upon the information presented.

☐ **Student Supplements.** This component is included in a unit of instruction when additional information is needed in order for students to complete one or more of the assignment and/or job sheets. Students are not directly tested over the information presented in a supplement; however, their ability to apply this information may be evaluated in the completion of assignment and/or job sheets.

Student Workbook



*Designates components that may not appear in every unit of instruction

The student workbook is an integral part of the student materials and should be provided to each student. It contains the pen-and-paper exercises and skill tests necessary for student mastery of the course.

☐ **Assignment Sheets.** The assignment sheets address the learning levels at or above the application level of Bloom's taxonomy. They provide students with an opportunity to use higher-order thinking skills, such as problem solving, synthesizing, analyzing, and evaluating. In addition, they may provide additional opportunities for students to develop their language skills.

Assignment sheets can be paper-and-pencil activities, as well as those using computer software, videotapes, models, handouts, or other resources as appropriate. Criteria are provided to evaluate student performance objectively.

☐ **Job Sheets.** Job sheets are designed as skill tests and give the instructor direction as to the psychomotor skills to be taught, and provide the criteria to evaluate student performance objectively. They also help provide potential employers with a picture of the skills being taught during training and the performances that might be reasonably expected from an individual who has completed the training.

The teacher should provide students with a copy of each job sheet and/or the procedure's manual and/or job specifications when necessary. The teacher should also discuss the equipment and materials that will be needed for the job and the criteria that will be used to evaluate the student's performance, and demonstrate the procedure prior to having students practice the procedure. Safety should be stressed as part of each demonstration.

When a student is ready to be evaluated, the teacher should follow the instructions for evaluating student performance which may be found in the suggested activities component of the teacher unit.

As you use these instructional materials we hope that you will find that they contribute to the quality of your program. If any problems occur or if you have any suggestions for improvement of the materials, please write us at 1500 West Seventh Avenue, Stillwater, OK 74074-4364, or e-mail us at mavcc@mavcc.com.

Gas Tungsten Arc Welding and Plasma Arc Cutting

Training and Competency Profile

Student Information

Program ______________________ Instructor ______________________

Name ______________________ Soc. Sec. No. ______________________

Address ______________________ Phone ______________________

Grade ______________ School ______________________

Allergies/Disabilities that might require special accommodation for training (please specify)

____

In case of emergency, contact ______________________ Phone ______________

Record of Enrollment

Date of Enrollment ____-____-____ Total Class Hours ________ Total Hours Absent ________

Date of Withdrawal ____-____-____ Total On-the-Job Training Hours ________ Total Hours Tardy ________

Date of Completion ____-____-____ Total Lab Hours ________

On-the-Job Training/Work Experience

______________________ ______________________
Place of Employment Address

______________________ ______________________
Supervisor's Name Phone

______________________ ______________________
Duration of Employment Job Title

____
Job Responsibilities

______________________ ______________________
Place of Employment Address

______________________ ______________________
Supervisor's Name Phone

______________________ ______________________
Duration of Employment Job Title

____
Job Responsibilities

Training and Competency Profile

Student Evaluation

Directions: Evaluate the student using the rating scale below. Write the appropriate number to indicate the degree of competency achieved. The descriptions associated with each of the numbers focuses on a level of student performance for each of the tasks listed. The written test scoreline is provided for optional teacher use. It may not be applicable in all cases.

Rating Scale: Option A	
4	Skilled—Can perform job with no additional training
3	Moderately Skilled—Has performed job during training program; limited additional training may be required.
2	Limited Skill—Has performed job during training program; additional training is required to develop skill.
1	Unskilled—Is familiar with process, but is unable to perform job.
0	No Exposure—No information or practice provided during training program, complete training required.
NA	Non-applicable.

Rating Scale: Option B

Yes—Can perform with no additional training
No—Is unable to perform satisfactorily

Unit 1: GTAW Orientation and Safety

_______ 1. Solve problems concerning GTAW safety.
_______ 2. _______________________
_______ Written Test Score

Unit 2: GTAW Equipment, Applications, and Techniques

_______ 1. Set up a flow meter regulator for GTAW shielding gases.
_______ 2. Set up and shut down GTAW equipment for welding mild or stainless steel.
_______ 3. Prepare mild or stainless steel for GTAW.
_______ 4. Prepare a tungsten electrode for welding mild or stainless steel.
_______ 5. Strike and maintain an arc to make stringer beads on mild or stainless steel without filler metal in the flat position.
_______ 6. Strike and maintain an arc to make stringer beads on mild or stainless steel with filler metal in the flat position.
_______ 7. Weld to specifications a fillet weld lap joint on mild or stainless steel in the flat position.
_______ 8. Weld to specifications a fillet weld T-joint on mild or stainless steel in the flat position.
_______ 9. Weld to specifications an open-root square-groove butt joint on mild or stainless steel in the flat position.
_______ 10. Weld to specifications a fillet weld lap joint on mild or stainless steel in the horizontal position.
_______ 11. Weld to specifications a fillet weld T-joint on mild or stainless steel in the horizontal position.
_______ 12. Weld to specifications a fillet weld lap joint on mild or stainless steel in the vertical position.
_______ 13. Weld to specifications a fillet weld T-joint on mild or stainless steel in the vertical position.
_______ 14. Weld to specifications an open-root square-groove butt joint on mild or stainless steel in the vertical position.
_______ 15. Weld to specifications a fillet weld lap joint on mild or stainless steel in the overhead position.
_______ 16. Weld to specifications a fillet weld T-joint on mild or stainless steel in the overhead position.
_______ 17. Set up and shut down GTAW equipment for welding aluminum.
_______ 18. Prepare aluminum for GTAW.
_______ 19. Prepare a tungsten electrode for welding aluminum.
_______ 20. Strike and maintain an arc to make stringer beads on aluminum without filler metal in the flat position.
_______ 21. Strike and maintain an arc to make stringer beads on aluminum with filler metal in the flat position.
_______ 22. Weld to specifications a fillet weld lap joint on aluminum in the flat position.
_______ 23. Weld to specifications a fillet weld T-joint on aluminum in the flat position.
_______ 24. Weld to specifications a square-groove butt joint on aluminum in the flat position.
_______ 25. Weld to specifications a fillet weld lap joint on aluminum in the horizontal position.
_______ 26. Weld to specifications a fillet weld T-joint on aluminum in the horizontal position.
_______ 27. Weld to specifications a fillet weld lap joint on aluminum in the vertical position.
_______ 28. Weld to specifications a fillet weld T-joint on aluminum in the vertical position.

_______ 29. Weld to specifications a square-groove butt joint on aluminum in the vertical position.
_______ 30. Weld to specifications a fillet weld lap joint on aluminum in the overhead position.
_______ 31. Weld to specifications a fillet weld T-joint on aluminum in the overhead position.
_______ 32. ______________________________
_______ Written Test Score

Unit 3: Plasma Arc Cutting

_______ 1. Prepare a PAC machine for operation.
_______ 2. Complete a contact cut on selected metal.
_______ 3. Complete a stand-off cut on selected metal.
_______ 4. Gouge mild steel plate with a PAC unit.
_______ 5. ______________________________
_______ Written Test Score

Permission to duplicate this profile is granted.

Gas Tungsten Arc Welding and Plasma Arc Cutting

State of Oklahoma Welding Duty/Task Crosswalk

The following state of Oklahoma welding tasks, which are aligned to AWS standards, are covered in this publication. The first column identifies Oklahoma's task by name and number. The second column identifies the exact location by unit number and objective, assignment sheet, or job sheet in this MAVCC publication unless otherwise noted.

Occupation: Gas Tungsten Arc Welder	MAVCC Tasks
Duty A: Demonstrate Employability Skills	
A.18 Identify employment opportunities	*Fundamentals of Welding*, Unit 1, Objective 7—Job outlook for welders; Objective 9—Career opportunities for welders; Assignment Sheet 2—Compare employment opportunities in welding
A.19 Identify levels of training recommended for related careers	*Fundamentals of Welding*, Unit 1, Objective 8—What it takes to become a good welder
A.20 Understand salary, wages and benefits packages	*Fundamentals of Welding*, Unit 1, Objective 6—What welders earn
Safety	
A.26 Explain the purpose for safety policies	*Fundamentals of Welding*, Unit 2, Objective 4—Hazard communication; Assignment Sheet 1—Complete the student safety pledge form; Assignment Sheet 5—Identify and correct safety violations
A.27 Discuss the role of OSHA and EPA — Locate information in MSDS	*Fundamentals of Welding*, Unit 2, Objective 6—Purposes of material safety data sheets; Student Supplement 1—Guidelines for interpreting material safety data sheets; Assignment Sheet 2—Interpret a material safety data sheet
A.28 Participate in OSHA training, if possible — Lock Out/Tag Out	*Fundamentals of Welding*, Unit 2, Objective 8—Safety tags and their color coding; Objective 19—Instances when lockout devices should be used
— HAZCOM	*Fundamentals of Welding*, Unit 2, Objective 4—Hazard communication
- MSDS	*Fundamentals of Welding*, Unit 2, Objective 6—Purposes of MSDS; Student Supplement 1—Guidelines for interpreting MSDS; Assignment Sheet 2—Interpret a material safety data sheet

State of Oklahoma Welding Duty/Task Crosswalk

Occupation: Gas Tungsten Arc Welder	MAVCC Tasks
— Bloodborne Pathogens	*Fundamentals of Welding*, Unit 3, Objective 18—Basic first-aid procedures for various emergency situations
A.29 Explain the proper steps in reporting an accident or emergency	*Fundamentals of Welding*, Unit 3, Objective 16—General steps for handling any emergency situation; Objective 17—General guidelines for first aid emergencies; Assignment Sheet 1—Determine basic first aid measures for given emergency situations
A.30 Explain the hazards associated with specific types of equipment and tools	*Fundamentals of Welding*, Unit 2, Objective 3—General job and shop safety rules; Assignment Sheet 5—Identify and correct safety violations *GTAW and PAC*, Unit 1, Objective 10—Rules for handling hollow castings and containers; Objective 11—Hazards associated with arc rays
A.31 Perform machine operator safety checks of equipment and accessories, when necessary	*Fundamentals of Welding*, Unit 2, Assignment Sheet 5—Identify and correct safety violations; Unit 4, Objective 21—Basic rules for safe use of power tools and equipment
A.32 Practice tool safety	*Fundamentals of Welding*, Unit 2, Objective 3d—Tool use, maintenance, and storage safety; Unit 3, Objective 9—Rules for handling welding cables and gas and coolant hoses; Unit 4, Objective 20—Rules for hand tool safety; Objective 21—Basic rules for safe use of power tools and equipment; Objective 22—Rules for tool and equipment maintenance
A.33 Describe the types of fire hazards found in the workplace	*Fundamentals of Welding*, Unit 2, Objective 10—Components of fire triangle; Objective 11—Types of fires and classifications; Objective 12—Types of fire extinguishers; Objective 13—Fire extinguisher markings and class of fire they represent; Objective 14—Fire extinguisher operating instructions that follow P-A-S-S; Student Supplement 2—Using Portable Fire Extinguishers; Assignment Sheet 4—Determine correct fire extinguishers to use for various situations; Job Sheet 1—Operate a fire extinguisher

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State of Oklahoma Welding Duty/Task Crosswalk

Occupation: Gas Tungsten Arc Welder	MAVCC Tasks
A.34 Discuss electrical hazards	*Fundamentals of Welding*, Unit 2, Objective 3f—Electrical safety; Unit 3, Objective 19—Treating a victim of electrical shock *GTAW and PAC*, Unit 1, Objective 7—Electrical safety guidelines for GTAW
A.35 Demonstrate safe use of personal protective equipment	*Fundamentals of Welding*, Unit 2, Objective 20—Fall protection systems; Objective 21—Confined space entry; Objective 22—Environmental contaminants that would require you to use a respirator *GTAW and PAC*—Unit 1, Objective 11—Hazards associated with arc rays; Objective 12—Types of welding hoods; Objective 13—Guidelines for selecting a safe lens shade for GTAW; Objective 14—Protective clothing required for arc welding; Objective 15—Environmental safety requirements
A.36 Demonstrate safe material handling techniques — Lifting — Transporting — Storing	*Fundamentals of Welding*, Unit 2, Objective 15—Causes of back injuries; Objective 16—Guidelines for lifting and moving items safely; Job Sheet 2—Lift a heavy object properly
A.37 Understand established first aid procedures	*Fundamentals of Welding*, Unit 3, Objective 16—General steps for handling any emergency situation; Objective 17—General guidelines for first aid emergencies; Objective 18—Basic first-aid procedures for various emergency situations; Student Supplement 2—A Systematic Look at First Aid; Assignment Sheet 1—Determine basic first aid measures for given emergency situations
A.38 Practice good housekeeping	*GTAW and PAC*—All job sheets require students to clean up their work areas and return tools and equipment to proper storage.
A.39 Comply with company safety policies	*Fundamentals of Welding*, Unit 2, Assignment Sheet 1—Complete the student safety pledge form

State of Oklahoma Welding Duty/Task Crosswalk

Occupation: Gas Tungsten Arc Welder	MAVCC Tasks
Basic Academic Skills	
A.40 Apply mathematical operations involving whole numbers, fractions, decimals, percentages, mathematical word problems, ratios, etc., when necessary — Addition — Subtraction — Multiplication — Division	*Fundamentals of Welding*, Unit 6, Assignment Sheet 1—Add, subtract, multiply, and divide fractions; Assignment Sheet 2—Add, subtract, multiply, and divide decimal equivalents; Assignment Sheet 3—Convert fractions to decimal form, change fractions to a common denominator, and reduce fractions to lowest terms; Assignment Sheet 4—Write fractions as decimals and percents; Assignment Sheet 6—Write decimals as fractions and percents; Assignment Sheet 8—Make conversions with an inches-to-decimal conversion chart
A.41 Apply advanced mathematical operations, when necessary — Algebra — Geometry — Trigonometry — Calculus — Statistical Methods	*Fundamentals of Welding*, Unit 6, Objective 8, Terms used in geometry; Objective 9—Types of geometric figures; Objective 12—Area of geometric figures; Assignment Sheet 14—Calculate area of geometric figures; Job Sheet 1—Adjust a bevel square to a 45° angle using a framing square, a combination square, and a protractor; Job Sheet 2—Form 90° and 45° angles with a combination square and draw parallel lines on metal stock
A.42 Apply scientific principles, when necessary — Physics — Chemistry	*Fundamentals of Welding*, Unit 5, Objective 4—Metal identification tests; Objective 5—Mechanical properties of metals; Objective 6—Types of mechanical strengths; Objective 7—Physical properties of metals; Job Sheet 1—Conduct magnet tests to identify common metals used for welding; Job Sheet 2—Conduct chisel tests to identify common metals used for welding; Job Sheet 3—Conduct spark tests to identify common metals used for welding
A.43 Interpret charts, table, and graphs	*Fundamentals of Welding*, Unit 6, Assignment Sheet 7—Make conversions with a decimal equivalent chart; Assignment Sheet 8—Make conversions with an inches-to-decimal conversion chart
A.44 Apply reading and writing skills, when necessary	Most assignment sheets require the student to read and write.

State of Oklahoma Welding Duty/Task Crosswalk

Occupation: Gas Tungsten Arc Welder	MAVCC Tasks
Blueprint Reading	
A.50. Identify basic elements of blueprints — Terms — Components — Symbols	*Fundamentals of Welding*, Unit 7, "Welding Print Reading" *Fundamentals of Welding*, Unit 7, Objective 1—Terms related to print reading; Objective 2—Basic lines; Objective 13—Symbols
A.51 Discuss different types of drawings	*Fundamentals of Welding*, Unit 7, Objective 4—Isometric and oblique drawings
A.52 Interpret drawings — Bill of Materials — Revisions — Tolerances	*Fundamentals of Welding*, Unit 7, Objective 4—Isometric and oblique drawings; Objective 6—Tolerancing; Objective 15—Requirements for a formal bill of material; Objective 16—Requirements for an informal bill of material; Assignment Sheet 5—Interpret tolerance dimensions in decimals, fractions, and degrees; Unit 8, Assignment Sheet 5—Interpret a welding print and welding procedure specifications
A.53 Interpret symbols	*Fundamentals of Welding*, Unit 7, Objective 13—Symbols
Measurement Tools and Techniques	
A.54 Identify types of measuring instruments	*Fundamentals of Welding*, Unit 6, Objective 6—Types of rules and examples of their graduations
A.55 Use appropriate measurement instrument for a measurement task	*Fundamentals of Welding*, Unit 6, Job Sheet 2—Form 90° and 45° angles with a combination square and draw parallel lines on metal stock
A.56 Read measuring instruments	*Fundamentals of Welding*, Unit 6, Objective 7—Steps in reading a rule; Assignment Sheet 9—Measure distances with 1″, 1/2″ and 1/4″ graduations; Assignment Sheet 10—Measure distances with 1/4″ and 1/8″ graduations; Assignment Sheet 12—Measure distances with 1/16″ graduations; Job Sheet 1—Adjust a bevel square to a 45° angle using a framing square, a combination square, and a protractor; Job Sheet 2—Form 90° and 45° angles with a combination square and draw parallel lines on metal stock

State of Oklahoma Welding Duty/Task Crosswalk

Occupation: Gas Tungsten Arc Welder	**MAVCC Tasks**
A.57 Identify the appropriate formula and units for a measurement task	*Fundamentals of Welding*, Unit 6, Objective 11—Squares, rectangles, and triangles and their formulas for calculating their perimeters; Objective 12—Area of geometric figures
A.58 Differentiate between English and Metric measurement systems, when necessary	*Fundamentals of Welding*, Unit 6, Objective 13—English-metric conversion charts and how to use them; Assignment Sheet 13—Make conversions with an English-metric conversion chart
A.59 Communicate measurements using proper symbols or words	*Fundamentals of Welding*, Unit 6, Objective 10—Units of measure and their equivalents
Duty B: Interpret Drawing and Welding Symbols and Written Welding Procedures	
B.01 Interpret basic elements of drawing/sketch	*Fundamentals of Welding*, Unit 7—Welding Print Reading (entire unit) *GTAW and PAC*—Unit 2, Job Sheets 5 through 16, 20 through 31
— Structural members	*Fundamentals of Welding*, Unit 7, Objective 14—Structural shapes
— Sequence of assembly	*Fundamentals of Welding*, Unit 7, Assignment Sheet 8—Construct adjacent parts in an assembly section
— Dimensions and tolerances	*Fundamentals of Welding*, Unit 7, Objective 5—Dimensioning; Objective 7—Methods of dimensioning; Assignment Sheet 5—Interpret tolerance dimensions in decimals, fractions, and degrees
— Scale	*Fundamentals of Welding*, Unit 7, Objective 9—Reduction and enlargement scales
— View interpretation	*Fundamentals of Welding*, Unit 7, Objective 3—Basic views; Objective 12—Types of section views; Student Supplement 2—Orthographic projection; Assignment Sheet 1—Construct a top view; Assignment Sheet 2—Construct a front view; Assignment Sheet 3—Construct a right side view; Assignment Sheet 7—Make a three-view sketch

State of Oklahoma Welding Duty/Task Crosswalk

Occupation: Gas Tungsten Arc Welder	**MAVCC Tasks**
— List of materials	*Fundamentals of Welding*, Unit 7, Objective 15—Requirements for a formal bill of materials; Objective 16—Requirements for an informal bill of materials
B.02 Interpret welding symbol information — Type of weld required — Filler metal — Special details — Non-destructive testing requirements	*GTAW and PAC*—Unit 2, Job Sheets 5 through 16, 20 through 31 *Fundamentals of Welding*, Unit 8, Basic Welding Joints and Symbols (entire unit)
B.03 Interpret written welding procedures — Procedure ID number cross-referencing to drawing — Appropriate welding process/base materials/filler materials — Appropriate machine settings	*GTAW and PAC*—Unit 2, "GTAW Equipment, Applications, and Techniques"—All job sheets
Duty F: Perform Gas Tungsten Arc Welding (GTAW)	
F.01 Perform safety inspections of equipment and accessories — Protective clothing and equipment — Hand tools — Welding equipment and accessories — Shielding gas equipment and accessories — Work area	*GTAW and PAC*, Unit 2—All job sheets require students to practice safety precautions. *Fundamentals of Welding*, Unit 2, "General Safety" and Unit 3, "Welding Safety and First Aid" cover safety in detail.
F.02 Make minor external repairs to equipment and accessories (preventative maintenance only) — Manufacturer's recommendations — Company repair policy — Equipment troubleshooting - Porosity - Gas leaks	*GTAW and PAC*, Unit 2, Objective 24—Guidelines for troubleshooting GTAW problems; Student Supplement 3—Troubleshooting guide for GTAW
F.03 Set up for gas tungsten arc welding operations on plain carbon steel, aluminum, and stainless steel plate — Review appropriate weld problems — Filler metal selection — Adjust voltage — Proper gas flow rate — Parts set up and preheated as necessary — Base metal preparation	*GTAW and PAC*, Unit 2, Job Sheet 1—Set up a flow meter regulator for GTAW shielding gases; Job Sheet 2—Set up and shut down GTAW equipment for welding mild or stainless steel; Job Sheet 17—Set up and shut down GTAW equipment for welding aluminum

State of Oklahoma Welding Duty/Task Crosswalk

Occupation: Gas Tungsten Arc Welder	MAVCC Tasks
F.04 Operate gas tungsten arc welding equipment	*GTAW and PAC*, Unit 2, Job Sheet 5—Strike and maintain an arc to make stringer beads on mild or stainless steel without filler metal in the flat position; Job Sheet 6—Strike and maintain an arc to make stringer beads on mild or stainless steel with filler metal in the flat position; Job Sheet 20—Strike and maintain an arc to make stringer beads on aluminum without filler metal in the flat position; Job Sheet 21—Strike and maintain an arc to make stringer beads on aluminum with filler metal in the flat position
— Make fillet and groove welds on plain carbon steel plate, aluminum and stainless steel plate — Workmanship	*GTAW and PAC*, Unit 2, Job Sheets 7 through 16, Job Sheet 22 through 31
F.05 Make fillet welds, 2F and 3F positions, on plain carbon steel plate — EWCe-2 electrodes	*GTAW and PAC*, Unit 2, Job Sheet 10—Weld to specifications a fillet weld lap joint on mild or stainless steel in the horizontal position; Job Sheet 11—Weld to specifications a fillet weld T-joint on mild or stainless steel in the horizontal position; Job Sheet 12—Weld to specifications a fillet weld lap joint on mild or stainless steel in the vertical position; Job Sheet 13—Weld to specifications a fillet T-joint on mild or stainless steel in the vertical position
F.06 Make groove welds, 3G position without backing, on plain carbon steel plate EWCe-2 electrodes Note: EWTh-2 production has been curtailed due to radiation problems.	*GTAW and PAC*, Unit 2, Job Sheet 14—Weld to specifications an open-root square-groove butt joint on mild or stainless steel in the vertical position
F.07 Make 1F-2F welds on aluminum plate — EWP &/or EWZr tungsten electrodes	*GTAW and PAC*, Unit 2, Job Sheet 22—Weld to specifications a fillet weld lap joint on aluminum in the flat position; Job Sheet 23—Weld to specifications a fillet weld T-joint on aluminum in the flat position; Job Sheet 25—Weld to specifications a fillet weld lap joint on aluminum in the horizontal position; Job Sheet 26—Weld to specifications a fillet weld T-joint on aluminum in the horizontal position
F.08 Make 1G with backing welds on aluminum plate EWP and/or EWZr tungsten electrodes	Not applicable

Occupation: Gas Tungsten Arc Welder	MAVCC Tasks
F.09 Make 1F-2F-3F welds on stainless steel plate EWCe-2 electrodes	*GTAW and PAC*, Unit 2, Job Sheet 7—Weld to specifications a fillet weld lap joint on mild or stainless steel in the flat position; Job Sheet 8—Weld to specifications a fillet weld T-joint on mild or stainless steel in the flat position; Job Sheet 10—Weld to specifications a fillet weld lap joint on mild or stainless steel in the horizontal position; Job Sheet 11—Weld to specifications a fillet weld T-joint on mild or stainless steel in the horizontal position; Job Sheet 12—Weld to specifications a fillet weld lap joint on mild or stainless steel in the vertical position; Job Sheet 13—Weld to specifications a fillet T-joint on mild or stainless steel in the vertical position
F.10 Make 1G-2G-3G welds on stainless steel plate EWCe-2 electrodes Note: EWTh-2 production has been curtailed due to radiation problems.	*GTAW and PAC*, Unit 2, Job Sheet 9—Weld to specifications an open-root square-groove butt joint on mild or stainless steel in the flat position; Job Sheet 14—Weld to specifications an open-root square-groove butt joint on mild or stainless steel in the vertical position
Duty G: Perform Manual Oxyfuel (OF) Cutting—Refer to *Oxyacetylene Welding and Cutting* for this duty.	
Duty I: Perform Air Carbon Arc Cutting (Gouging)—Refer to *Shielded Metal Arc Welding* for this duty.	
Duty J: Perform Plasma Arc Cutting and Gouging	
J.01 Perform safety inspections of equipment and accessories — Protective clothing and equipment — Plasma arc cutting equipment and accessories — Compressed gas system and accessories — Required tools — Work area — Communicate hazard warnings	*GTAW and PAC*, Unit 3, Objective 4—Plasma arc electrical safety; Objective 5—Plasma arc environmental safety; Objective 6–Plasma arc workplace safety; All job sheets require students to practice safety precautions. *Fundamentals of Welding*, Unit 2, "General Safety" and Unit 3, "Welding Safety and First Aid" cover safety in detail.

State of Oklahoma Welding Duty/Task Crosswalk

Occupation: Gas Tungsten Arc Welder	**MAVCC Tasks**
J.02 Make minor external repairs to equipment and accessories (preventative maintenance only) — Manufacturer's recommendations — Company repair policy — Equipment troubleshooting (clean gas and tip)	*GTAW and PAC*, Unit 3, Objective 13—PAC consumables, their characteristics and maintenance; Objective 22—Common cutting problems and their probable causes
J.03 Set up for manual plasma arc cutting operations on plain carbon steel, aluminum, and stainless steel plate — Regulator set for appropriate plasma gas — Tip selection based on gas	*GTAW and PAC*, Unit 3, Job Sheet 1—Prepare a PAC machine for operation
J.04 Operate manual plasma arc cutting equipment	*GTAW and PAC*, Unit 3, Job Sheet 2—Complete a contact cut on selected metal; Job Sheet 3—Complete a stand-off cut on selected metal
J.05 Perform shape cutting operations on plain carbon steel, aluminum, and stainless steel plate	Not applicable
Duty K: Perform Welding Inspection and Testing	
K.01 Examine cut surfaces and edges of prepared base metal parts — Appearance — Uniformity — Proper fit-up — Base metal preparation	*GTAW and PAC*, Unit 2, Job Sheets 7 through 16, Job Sheets 22 through 31
K.02 Examine tack, intermediate layers, and completed welds — Visual check for weld discontinuity and defects to an acceptable criteria — Destructive or non-destructive examination	*GTAW and PAC*, Unit 2, Job Sheets 7 through 16, Job Sheets 22 through 31

Instructional/Task Analysis

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 1: GTAW Orientation and Safety

1. Terms and definitions
2. Advantages of the GTAW process
3. Limitations of the GTAW process
4. Principles of GTAW
5. GTAW applications
6. Benefits from learning GTAW
7. Electrical safety guidelines for GTAW
8. Guidelines for duty cycle safety
9. Rules for handling welding cables and gas and coolant hoses
10. Rules for handling hollow castings and containers
11. Hazards associated with arc rays
12. Types of welding hoods
13. Guidelines for selecting a safe lens shade for GTAW
14. Protective clothing requirements for GTAW
15. Environmental safety requirements
16. Solve problems concerning GTAW safety

Unit 2: GTAW Equipment, Applications, and Techniques

1. Terms and definitions
2. GTAW machine controls and their functions
3. Concept of pulse current and its use in GTAW
4. Types of GTAW systems
5. Cooling system safety
6. Types of power cables and their characteristics
7. Parts of a GTAW torch
8. Gas lens and its uses

Instructional/Task Analysis

Unit 2: GTAW Equipment, Applications, and Techniques (continued)

Related Information: What the Student Should Know

9. Types of nozzles and their functions
10. Steps in GTAW nozzle selection
11. GTAW shielding gases and their characteristics
12. Flow meter design and use
13. Flow rates for GTAW shielding gases
14. Tungsten electrodes, their characteristics and applications
15. Guidelines for preparing tungsten electrodes for DC welding
16. Guidelines for grinding electrodes for DC welding
17. Guidelines for preparing electrodes for AC welding
18. Guidelines for GTAW electrode extension
19. Guidelines for filler metal selection and use
20. Requirements for base metal preparation
21. Special problems with contamination and air movement
22. Steps for manual welding with a filler rod
23. Backup bars and their use in GTAW
24. Guidelines for troubleshooting GTAW problems

Application: What the Student Should Be Able to Do

25. Set up a flow meter regulator for GTAW shielding gases
26. Set up and shut down GTAW equipment for welding mild or stainless steel
27. Prepare mild or stainless steel for GTAW
28. Prepare a tungsten electrode for welding mild or stainless steel
29. Strike and maintain an arc to make stringer beads on mild or stainless steel without filler metal in the flat position
30. Strike and maintain an arc to make stringer beads on mild or stainless steel with filler metal in the flat position
31. Weld to specifications a fillet weld lap joint on mild or stainless steel in the flat position
32. Weld to specifications a fillet weld T-joint on mild or stainless steel in the flat position
33. Weld to specifications an open-root square-groove butt joint on mild or stainless steel in the flat position
34. Weld to specifications a fillet weld lap joint on mild or stainless steel in the horizontal position
35. Weld to specifications a fillet weld T-joint on mild or stainless steel in the horizontal position
36. Weld to specifications a fillet weld lap joint on mild or stainless steel in the vertical position
37. Weld to specifications a fillet weld T-joint on mild or stainless steel in the vertical position
38. Weld to specifications an open-root square-groove butt joint on mild or stainless steel in the vertical position
39. Weld to specifications a fillet weld lap joint on mild or stainless steel in the overhead position

Related Information: What the Student Should Know	Application: What the Student Should Be Able to Do

Unit 2: GTAW Equipment, Applications, and Techniques (continued)

40. Weld to specifications a fillet weld T-joint on mild or stainless steel in the overhead position
41. Set up and shut down GTAW equipment for welding aluminum
42. Prepare aluminum for GTAW
43. Prepare a tungsten electrode for welding aluminum
44. Strike and maintain an arc to make stringer beads on aluminum without filler metal in the flat position
45. Strike and maintain an arc to make stringer beads on aluminum with filler metal in the flat position
46. Weld to specifications a fillet weld lap joint on aluminum in the flat position
47. Weld to specifications a fillet weld T-joint on aluminum in the flat position
48. Weld to specifications a square-groove butt joint on aluminum in the flat position
49. Weld to specifications a fillet weld lap joint on aluminum in the horizontal position
50. Weld to specifications a fillet weld T-joint on aluminum in the horizontal position
51. Weld to specifications a fillet weld lap joint on aluminum in the vertical position
52. Weld to specifications a fillet weld T-joint on aluminum in the vertical position
53. Weld to specifications a square-groove butt joint on aluminum in the vertical position
54. Weld to specifications a fillet weld lap joint on aluminum in the overhead position
55. Weld to specifications a fillet weld T-joint on aluminum in the overhead position

Instructional/Task Analysis

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 3: Plasma Arc Cutting

1. Terms and definitions
2. Basic characteristics of plasma arc cutting
3. Basic components and their functions in an air cut PAC system
4. Plasma arc electrical safety
5. Plasma arc environmental safety
6. Plasma arc workplace safety
7. Advantages of plasma arc cutting
8. Characteristics of plasma arc transfer modes
9. Guidelines for PAC electrode selection
10. Guidelines for cutting nozzle selection and installation
11. Shielding cups, their design and uses
12. Plasma air and secondary air used with PAC
13. PAC consumables, their characteristics and maintenance
14. PAC system duty cycles
15. Guidelines for setting PAC flow rate and flow pressure
16. Guidelines for using compressed air with a PAC system
17. Factors affecting cutting speeds
18. Techniques for contact and stand-off cutting
19. Techniques for cutting expanded metal
20. Techniques for gouging metal
21. Techniques for piercing and beveling metal
22. Cutting problems and their probable causes

23. Prepare a PAC machine for operation
24. Complete a contact cut on selected metal
25. Complete a stand-off cut on selected metal
26. Gouge mild steel plate with a PAC unit

Basic Skills Icons and Classifications

To assist teachers and students in identifying and documenting where academic and workplace skills are being taught, MAVCC has adopted a system that uses icons and a list of specific tasks to identify the skill or skills that are used in each assignment sheet and job sheet.

A matrix for each of the ten broad skill areas has been included in this edition and reflects key elements from *What Work Requires of Schools: A SCANS Report for America 2000*, a 1991 study by the U.S. Department of Labor; *Workplace Basics: The Skills Employers Want*, a three-year study conducted jointly by the American Society for Training and Development (ASTD) and the United States Department of Labor (DOL); and other national and state sources.

Each of the ten broad skill areas—reading, writing, math, science, oral communication, interpersonal or relating, critical thinking, employability, social studies, and technology—is represented by the icon presented below.

Reading Skills

- Reading Comprehension
- Research/Reference
- Functional Reading

Writing Skills

- Language
- Composition
- Research
- Functional Writing

Math Skills

- Operation and Calculation
- Math Application
- Data Analysis and Display
- Functional Math

Basic Skills Icons and Classifications

Science Skills

- General Science
- Life Science
- Physical Science
- Earth Science

Oral Communication Skills

- Oral Presentation
- Listening
- Interactive Communication

Interpersonal or Relating Skills

- General Relating
- Teamwork/Cooperation
- Leadership/Influence

Critical Thinking Skills

- Cognitive Activities

Employability Skills

- Job Search/Selections
- Job Acquisition/Development
- Resource Management
- Job Safety

Social Studies Skills

- Information Analysis
- Social Studies Application
- Functional Social Studies

Technology Skills

- Selection
- Application
- Maintenance/Troubleshooting

Reading Skills

Reading Comprehension

- Gain factual information
- Distinguish fact, opinion, and inference
- Recognize stereotyping and bias
- Recognize propaganda
- Analyze cause and effect
- Draw conclusions
- Make generalizations
- React to written material
- Apply word analysis techniques
- Analyze and apply what has been read to specific task
- Comprehend written information for main ideas
- Determine what information is needed

Research/ Reference

- Select useful resources
- Locate resources
- Find materials in library
- Use standard references
- Use in-book reference tools
- Use audiovisual media
- Use computer database
- Use magazines and newspapers

Functional Reading

- Interpret forms and records
- Follow written instructions
- Interpret graphics and symbols
- Interpret abbreviations/acronyms
- Read aloud
- Apply/understand technical words that pertain to subject

Writing Skills

Language	• Use standard grammar, spelling, and capitalization • State ideas clearly
Composition	• Use complete sentences • Develop preliminary outline • Use topic sentences • Use introductory/closing paragraphs • Compose reports • Compose essays • Proofread and edit • Construct graphics and symbols
Research	• Take notes • Use note cards • Create bibliography • Use footnotes • Outline material
Functional Writing	• Complete forms and records • Write instructions • Write letters • Write job applications • Write resumes • Use word processing • Use computer graphics • Use content area vocabulary

Math Skills

Operation and Calculation

- Round off numbers
- Estimate answers
- Use scientific notations
- Use exponential notations
- Calculate with whole numbers
- Calculate with fractions
- Calculate with decimals
- Convert whole numbers to fractions
- Convert whole numbers to decimals
- Solve numerical expressions
- Solve formulae and equations
- Obtain squares and square roots
- Convert units of measure
- Perform metric calculations

Math Application

- Solve word problems
- Select/apply mathematical formula
- Select/apply mathematical procedure
- Use English and metric measures
- Solve time/rate/distance problems
- Solve ratio/proportion problems
- Solve percent problems
- Apply techniques of scaling
- Apply algebra principles
- Apply geometry principles
- Apply trigonometry principles

Data Analysis and Display

- Interpret charts and tables
- Interpret graphs
- Collect/record data
- Apply sampling techniques
- Apply principles of probability
- Construct charts and tables
- Construct graphs
- Calculate statistics
- Interpret statistics
- Interpret plans/blueprints
- Draw facility to scale

Math Skills (Continued)

Functional Math

- Make measurements
- Perform banking transactions
- Make change
- Solve practical problems
- Calculate gross earnings
- Solve income/expense problems
- Prepare a budget
- Calculate interest
- Solve interest problems
- Calculate sales tax
- Determine income tax
- Use calculator for computation
- Use computer for computation
- Use computer spreadsheets
- Apply computation skills as they are actually used on the job
- Calculate measurements taken from measuring devices
- Perform/prepare an inventory
- Calculate and compare shipping costs
- Prepare financial report

Science Skills

General Science

- Apply computing skills
- Apply scientific method of inquiry
- Conduct experiments
- Investigate science ethics
- Investigate science history
- Investigate/apply economics in technology
- Use scientific instruments
- Investigate/apply technology
- Collect specimens
- Construct model to depict basic concept of ----

Life Science

- Identify/classify living organisms
- Investigate biological history of the earth
- Investigate food chains, webs, pyramids
- Investigate/apply principles of human development
- Investigate/apply principles of genetics/heredity
- Investigate/apply principles of anatomy/physiology
- Investigate health issues
- Observe health code/sanitation requirements

Physical Science

- Analyze/classify matter
- Investigate forms/changes of matter
- Investigate forms/changes of energy
- Investigate/apply chemical properties
- Investigate/apply physical laws

Earth Science

- Investigate physical characteristics of the earth
- Investigate geological history of the earth
- Investigate physical forces acting on the earth
- Solve problems of longitude, latitude, and time zones
- Investigate conservation of physical resources
- Investigate conservation of living resources
- Investigate issues of environmental impact
- Apply science principles to environmental issues

Oral Communication Skills

Oral Presentation

- Make informative presentations
- Make persuasive presentations
- Present personal opinion/viewpoint
- Use good speaking techniques
- Select/use words effectively
- Use effective body language
- Present appropriate appearance
- Integrate audio and/or visual materials into oral presentations
- Adapt presentation to specific audience

Listening

- Apply active listening skills
- Distinguish fact, opinion, and inference
- Draw conclusions/make generalizations
- Analyze/identify point of view

Interactive Communication

- Give/follow oral directions
- Apply questioning techniques
- Conduct/receive interviews
- Analyze/apply nonverbal communication
- Work effectively in a group
- Communicate with clients/customers/patients
- Communicate with coworkers
- Communicate with supervisors
- Communicate with professional colleagues/associates
- Apply telephone etiquette

Interpersonal or Relating Skills

General Relating

- Investigate/apply communication process models
- Analyze/apply nonverbal communication
- Investigate/apply cross-cultural communication
- Interact with coworkers
- Interact with supervisors
- Interact with clients/customers/patients
- Interact with professional colleagues/associates
- Interact with family/friends
- Participate in group activities
- Participate in industrial relations/functions
- Identify personal values/attitudes
- Apply information to life experiences

Teamwork/ Cooperation

- Identify values/attitudes
- Identify needs/drives
- Select/apply appropriate behavior
- Investigate/identify personal styles
- Investigate/identify group/corporate climate
- Give/receive feedback
- Identify hidden purposes
- Investigate/apply group dynamics
- Control undesirable/inappropriate behavior
- Resolve conflicts
- Clarify goals/objectives
- Devise "win/win" situations
- Build consensus
- Generate ideas
- Present point of view

Leadership/ Influence

- Analyze/apply leadership styles
- Analyze/apply management styles
- Obtain confidence of others
- Develop esteem in self/others
- Persuade others
- Analyze/apply motivation techniques
- Provide positive coaching

Basic Skills

Critical Thinking Skills

Cognitive Activities

- Collect/record information
- Identify critical elements/issues
- Define a problem
- Identify underlying causes
- Apply a problem-solving model
- Analyze/synthesize information
- Identify/analyze underlying assumptions
- Draw conclusions
- Predict results/outcomes
- Identify/evaluate consequences
- Identify/develop alternatives
- Evaluate alternatives
- Select an alternative
- Devise a solution
- Create a finished product
- Apply intuitive thinking techniques
- Transfer knowledge/training to new situations
- Apply new technology
- Develop an action plan
- Evaluate results/outcomes
- See relationship between two or more ideas, objects, or situations

Employability Skills

Job Search/ Selections

- Analyze personal occupational aptitudes/preferences
- Investigate employment prospects of a career field/occupation
- Investigate training requirements for a career field/occupation
- Investigate benefits of a career field/occupation
- Compare/evaluate career options
- Analyze impact of work on individual and family life

Job Acquisition/ Development

- Develop personal career path
- Locate appropriate jobs
- Analyze duties/requirements/benefits of specific job
- Master specific job task/procedure
- Complete job-related applications
- Write a letter of application
- Write personal resume
- Interview for a job
- Apply business etiquette
- Practice good work habits/attitudes
- Practice good personal presentation
- Develop self confidence/esteem
- Develop effective leadership
- Deal effectively with supervisors
- Deal effectively with coworkers
- Deal effectively with professional colleagues/associates
- Deal effectively with customers/clients/patients
- Follow established rules, regulations, and policies
- Promote the goals and values of the organization
- Exert a high level of effort and perseverance towards goal attainment
- Set high standards for self in completion of a task

Resource Management

- Complete task in timely manner
- Determine cost, time, and resources to complete a task
- Perform routine tasks related to equipment operation and/or maintenance

Job Safety

- Demonstrate safe use of tools, equipment, and supplies
- Observe safety rules
- Wear safety equipment
- Follow safety procedures
- Demonstrate proper use of safety device

Social Studies Skills

Information Analysis

- Collect/record data
- Interpret graphical information
- Construct graphical information
- Interpret maps/globes
- Interpret statistical information
- Analyze/interpret demographic information
- Distinguish trends and predicts impact of actions on systems operations

Social Studies Application

- Investigate/apply U.S. history
- Investigate/apply world history
- Investigate/apply U.S. geography
- Investigate/apply world geography
- Investigate/apply principles of government/politics
- Investigate/apply principles of economics
- Investigate/apply principles of ethics
- Investigate/apply principles of sociology
- Investigate/apply cross-cultural studies

Functional Social Studies

- Practice responsible personal economics
- Prepare a personal budget
- Use credit responsibly
- Practice good work ethics
- Participate in industrial relations
- Interact with people of different races/cultures
- Investigate/participate in government
- Investigate/apply American legal practices
- Select/use sources of information on current events
- Analyze current events
- Analyze consumer issues
- Analyze social issues
- Analyze conservation/ecology issues
- Analyze social impact of science/technology
- Analyze economic impact of science/technology
- Understand how social, organizational, and technological systems work and operate effectively

Technology Skills

Selection	• Choose procedures, tools, or equipment including computers and related technologies that will produce the desired results
Application	• Demonstrate the proper procedures for setting up and operating equipment, including computers and their programming systems
Maintenance/ Troubleshooting	• Perform maintenance on equipment, including computers and other technologies • Identify and correct problems with equipment • Report damaged or broken equipment to appropriate individual

BASIC SKILLS MATRIX

	Reading	Writing	Mathematics	Science	Oral Communication	Interpersonal	Critical Thinking	Employability	Social Studies	Technology
Unit 1 GTAW Orientation and Safety	X	X					X	X		
Unit 2 GTAW Equipment, Applications, and Techniques	X		X				X	X		X
Unit 3 Plasma Arc Cutting	X						X	X		X

Tools, Equipment, and Materials List

GTAW Tools, Equipment and Materials

- Adjustable wrench
- Air-cooled GTAW torch and cables
- Aluminum plate
- Argon shielding gas
- Brass ground clamp
- C-clamps
- Clean shop rags
- Cleaner/deoxidizer solution
- Coolant
- Copper block (thick)
- Fine grit grinding wheel (minimum 120-grit)
- Flow meter
- Gap wire (1/16" and 3/32")
- Grinding wheel (minimum 120-grit)
- GTAW machine
- GTAW machine accessories (preferred)
  - High frequency control
  - High frequency intensity rheostat
  - Pulse mode setting
  - Remote control switch (foot or hand)
  - Soft-start switch
- GTAW torch parts (for both demonstration and use)
  - Assorted cups (ceramic, fused quartz, metal, or alumina)
  - Cap
  - Collet
  - Torch body
- Helium shielding gas
- Mild steel plate
- Open-end wrench (7/8" and 1 1/8")
- Pedestal grinder
- Personal safety clothing for each student
- Pliers
- Safety glasses and face shields
- Sander/grinder
- Selected filler metal rods
- Soapstone
- Stainless steel brush
- Stainless steel plate
- Tungsten electrodes as selected by instructor
- Water-cooled GTAW torch and cables
- Wire brush

Tools, Equipment, and Materials List

PAC Tools, Equipment and Materials

- C-clamps
- Dual-air PAC machine
- Earplugs or protective muffs
- Metal as selected by instructor
- PAC machine accessories
  - Attached or in-line filter
  - Component tools
  - Compressed air supply
  - P.S.I. gauge
- PAC torch and accessories
  - Contact shielding cup
  - Gouging nozzle
  - Nozzle assortment/cutting
  - Regular gas cup or device
  - Replacement hafnium electrodes
  - Stand-off gas cup or device
- Personal safety clothing for each student
- Soapstone
- Straightedge
- Welding helmet or goggles with minimum #9 lens shade
- Wire brush

Unit 1 GTAW Orientation and Safety

Unit Contents

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Written Test 1-9

Answers to Written Test 1-17

Student Components

Student Page

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Objective Sheet 1-5

Information Sheet 1-7

*Assignment Sheet

1—Solve Problems Concerning GTAW Safety 1

*The Assignment Sheet is located in the Student Workbook.

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom.

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the assignment sheet. Review with students the criteria for evaluation of this activity.

Suggested Activities

Teaching Suggestions

- Use Objectives 5 and 6 to point out to students the advantages of GTAW in industry and the advantages for students who become skilled in GTAW applications.
- Discuss duty cycle safety in Objective 8 with special emphasis on the slower welding speeds associated with GTAW and the need for students to develop a new awareness of duty cycle and its importance to the GTAW process.
- Review general welding safety as you teach the final seven objectives in this unit. Stress lens shade selection and point out that lens shade selection for GTAW is different from that for SMAW, and why it is different.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the assignment sheet. Rate the student using the criteria listed on the assignment sheet. See Answers to Assignment Sheet for correct answers where applicable. If the student's performance is unacceptable, have the student review the appropriate materials and complete the assignment again.
- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Connor, Leonard, P., ed. *Welding Technology, Welding Handbook*, 8th ed. Vol. 1. Miami, FL: American Welding Society, 1987.
- O'Brien, R.L., ed. *Welding Processes, Welding Handbook*. 8th ed. Vol. 2. Miami, FL: American Welding Society, 1991.
- *The Procedure Handbook of Arc Welding*. 13th ed. Cleveland, OH: The Lincoln Electric Company, 1994.

Suggested Supplemental Resources

Print Media

- *Gas Tungsten Arc Welding Guide Book* (Item no. JFLF-834)—This book is available from:

  The Lincoln Electric Company
  22801 St. Clair Avenue,
  Cleveland, OH 44117-1199
  Fax: 216.881.2326

- *Gas Tungsten Arc Welding* poster (Item no. EW-324) is available from:

  Hobart Institute of Welding Technology
  400 Trade Square East
  Troy, OH 45373
  800.332.9448
  www.welding.org

Electronic Media

- Videos

  — *Arc Welding Safety* (11 min.)—This video provides a review of arc welding safety, safety hazards, and health hazards associated with this type of welding operation. (English and Spanish) 1011H

  — *Health and Safety Factors in Welding Operation* (27 min.)—This video educates welders on potential health and safety concerns in this occupation. 9018A

  The videos listed above are available from MAVCC at www.mavcc.org, or call 800.654.3988. Most videos are also available in CD-ROM format.

  — *Gas Tungsten Arc Welding (TIG)*—This entry-level video explains the importance of weld current polarity with the use of easy-to-understand graphics. Tungsten electrodes, shielding gases, and weld preparation are also examined. (18 min.) Available from:

  Miller Electric Manufacturing Co.
  1635 W. Spencer St.
  P.O. Box 1079
  Appleton, WI 54912-1079
  920.734.9821
  www.millerwelds.com

Suggested Activities

- *Gas Tungsten Arc Welding* (V20.0)—These videos cover 28 topics. Available from:

  Hobart Institute of Welding Technology
  400 Trade Square East
  Troy, OH 45373
  800.332.9448
  www.welding.org

- *TIG Welding for Beginners* (NIM-CC-14-V92)—Introduces TIG welding and electrodes, gases and equipment. Explains uses of DC and AC. Demonstrates welding on stainless steel using DC. (14 min.) Available from:

  NIMCO
  102 Hwy. 81 North
  P.O. Box 9
  Calhoun, KY 42327-0009
  800.962.6662
  www.nimcoinc.com

Answers to Assignment Sheet

Assignment Sheet 1

Solve Problems Concerning GTAW Safety

Note: Student answers should approximate those given.

1. Yes. Clean up water and dry the area, or cover the area with a suitable insulating material.
2. Yes. Put cables in a safe and proper place, never on a cylinder.
3. Yes. Put a darker shade lens in the helmet or check for cracks in the lens seal.
4. Yes. Wear a face shield or a flip-type welding hood when grinding or sanding.
5. Yes. Check area for proper ventilation and have operator stand to one side of fumes.

Written Test

Name ______________________________

Date ______________________ Score __________

Objective 1

Match the terms with their definitions.

1. Backup purge
2. Contaminants
3. Deposition rate
4. Gas tungsten arc welding (GTAW)
5. Heliarc
6. Inert gas
7. Nonconsumable
8. Oxygen displacement
9. Pulsed gas tungsten arc welding
10. Shielding gas
11. Toxic hazards

_____ a. An arc welding process that produces coalescence of metals by heating them with an arc between a nonconsumable tungsten electrode and a workpiece; shielding is obtained from a gas

_____ b. A trade name sometimes used to identify the gas tungsten arc welding process when helium is used as the primary gas; it is very expensive

_____ c. The weight of filler metal placed onto a weld in a given period of time

_____ d. Poisonous gases, fumes, and vapors produced by chemical reactions in certain welding processes

_____ e. Protective gas used to prevent atmospheric contamination during a welding procedure

_____ f. A gas that normally does not combine chemically with a base metal or filler metal

_____ g. A gas supplied to the back side of a weldment to prevent atmospheric contamination during the root pass

_____ h. A gas tungsten arc welding process variation in which the current is pulsed from a low (background) value to a high (peak) value

_____ i. The tendency of any arc or flame to reduce oxygen in the breathing zone around a welding activity

_____ j. Elements in the atmosphere and/or impurities formed from chemical reactions between a base metal, filler metal, electrode, or shielding gas

_____ k. Material that does not melt or transfer to a weld

Written Test

Objective 2

Select true statements concerning the advantages of GTAW by placing an "X" in the blanks next to the true statements.

_____ a. High quality welds can be made in all weldable metals and alloys including the very low melting alloys.

_____ b. GTAW uses no flux, produces no slag or spatter, and requires no after-weld cleaning.

_____ c. The controlled heat concentration with GTAW reduces distortion and stress in base metals.

_____ d. The GTAW process is good for welding thick or bulky items in a variety of metals.

_____ e. With GTAW, the operator can clearly see the arc and weld puddle, and the operator has close control of current and the welding process.

_____ f. Filler metal can be added to the weld pool independently.

Objective 3

Select true statements concerning the limitations of GTAW by placing an "X" in the blanks next to the true statements.

_____ a. GTAW will not function in a windy environment.

_____ b. Deposition rate with GTAW is high, compared to other processes.

_____ c. Equipment is more costly for start up than for GMAW or SMAW.

_____ d. The faster welding speeds with GTAW increase production costs.

_____ e. GTAW requires no skill to master the process.

Objective 4

Complete statements concerning principles of GTAW by circling the material that best completes each of the following statements.

a. The heat needed for fusion is generated by an arc between a **(nonconsumable) (consumable)** tungsten electrode and a base metal.

b. As heat is generated from the arc, a shielding **(flux) (gas)** surrounds the arc stream and the molten puddle formed by the arc and helps to stabilize the arc and protect the puddle from contaminants.

c. Filler metal may be added with a filler rod inserted into the weld puddle where it is also protected by the **(shielding gas) (stabilizing flux)**.

Objective 5

Complete statements concerning GTAW applications by circling the material that best completes each of the following statements.

a. With GTAW, welding is possible **(in flat, horizontal, and vertical) (in all)** positions.

b. GTAW can be done on a wide range of metals and **(thicknesses) (limited thicknesses)**.

c. GTAW is especially effective where precise **(heat) (deposition)** control is necessary for a quality weld such as in aircraft assembly or small, irregular shaped objects.

d. GTAW is good to excellent for all aluminum applications, and especially good on other thin **(ferrous and nonferrous) (nonferrous)** metals.

Objective 6

Complete statements concerning benefits from learning GTAW by circling the material that best completes each of the following statements.

a. GTAW introduces a beginning welder to the concept of a **(nonconsumable) (consumable)** electrode and shielding **(gases) (fluxes)** and their uses.

b. GTAW challenges the student to improve manipulative skills and **(eye-hand coordination) (welding know how)**.

c. Beginning welders may go to work in a place where there is no opportunity to learn GTAW, so learning GTAW early provides a beginner with an opportunity to achieve skills that will bring **(better jobs and high pay) (rapid advancement)**.

Objective 7

Select true statements concerning electrical safety guidelines for GTAW by placing an "X" in the blanks next to the true statements.

_____ a. All electrical equipment should have an earth ground for safety reasons, and this ground should be the same as the work lead to workpiece ground that completes the welding circuit.

_____ b. Keep electrical connections tight, clean, and dry because poor connections can heat up, cause bad welds, produce dangerous arcs and sparking, and even melt.

_____ c. Keep work area, equipment, and clothing dry because even a slight amount of moisture can conduct enough electricity to cause a severe shock.

_____ d. Never dip a torch in water to cool it, unless the torch is exceptionally hot.

_____ e. Disconnect and lock out all electric power sources before doing any work on electrical equipment.

_____ f. Keep welding cables as close to the work area as possible and do not connect cables to building framework because current can be directed through lifting chains and cables and weaken them.

_____ g. When working in high places, carefully examine work area for electrical hazards because a shock in such conditions could cause a fall and severe injury.

_____ h. When using a high frequency intensity control for GTAW, set the control at a maximum setting for the job activity to avoid getting interference from nearby communications equipment.

_____ i. Make sure that all GTAW machines using high frequency controls have both input and output grounded to avoid erratic frequency interference.

Objective 8

Solve problems concerning guidelines for duty cycle safety by circling the number of the item that best solves each of the following problems.

a. You are working with a GTAW machine that has a duty cycle of only 10 percent. You know to:

(1) Increase amperage to accomplish more welding in a shorter time.
(2) Pay careful attention to the actual time you spend welding.
(3) Stop every ten minutes to let the machine cool.

b. You are working with a GTAW machine that has a 20 percent duty cycle. You estimate the welding job will take at least 30 minutes. You know to:

(1) Operate the machine 6 minutes and then allow it to cool for 6 minutes.
(2) The duty cycle will cover the entire time span so just complete the weld and be done with it.
(3) Operate the machine no more than 2 minutes out of each 10 minute period.

Objective 9

Select true statements concerning important rules for handling welding cables and gas and coolant hoses by placing an "X" in the blanks next to the true statements.

_____ a. Never drag cables or hoses through dirt or oil, and never pull a cable to force it over an obstruction.

_____ b. Use only solvent and rags to clean cables and hoses.

_____ c. When not in use, keep cables and hoses coiled free of kinks and properly stored.

_____ d. Never drape a welding cable over any type of gas cylinder, and NEVER strike an arc on a gas cylinder.

_____ e. Never interchange gas and water hoses without purging them first.

_____ f. Disconnect and remove electrode holders and cables used for SMAW.

_____ g. Keep cables off metal tables or any grounding surfaces.

_____ h. Make sure water-cooled systems have water turned off when shutting down.

_____ i. Use welding cable covers.

Objective 10

Select true statements concerning rules for handling hollow castings and containers by placing an "X" in the blank(s) next to the true statement(s).

_____ a. Vent hollow castings or containers before heating, cutting, or welding on them.

_____ b. Do not heat, cut, or weld on tanks, drums, and sealed containers unless you know they're empty.

Objective 11

Complete statements concerning hazards associated with arc rays by circling the material that best completes each of the following statements.

a. A GTAW arc produces ultraviolet and infrared **(radiation) (light)** that can severely burn eyes that are unprotected with a proper shade of protective lens.

b. **(Radiation) (Light)** from a GTAW arc is strong enough to sunburn or sometimes **(discomfort) (blister)** bare skin if the exposure is intense or for an extended period, so arms, legs, and torso should be covered with durable flame-resistant clothing.

c. Workstations and work areas should be **(shielded) (marked)** to prevent an arc flash from injuring nearby workers or visitors.

Objective 12

Complete statements concerning types of welding hoods and their characteristics by circling the material that best completes each statement.

a. Stationary filter lens—This type hood has a **(fixed) (flexible)** lens housing with the shaded lens held in by a spring retainer from where a lens can be slipped out and replaced as welding requires.

b. Flip-front filter lens—This type hood has a lens housing with a front side that can be flipped up so that it leaves a **(dark) (clear-glass or plastic)** lens that permits the hood to be worn while chipping.

c. Auto darkening lens—This type of lens contains sensors that automatically change the shade lens from **(clear to dark) (dark to clear)** in a fraction of a second when you start to weld.

Written Test

Objective 13

Solve problems concerning guidelines for selecting a safe lens shade for GTAW by circling the number of the item that best solves each of the following problems.

a. You notice a fellow worker putting a #5 lens into a helmet in preparation for a GTAW job. The welder would do well to:

   (1) Remember to weld for only short periods with a #5 lens.
   (2) Weld for no longer than 5 minutes at a time with a #5 lens because that's what the #5 means.
   (3) Remember not to use the GTAW process with anything less than a #8 lens and increase the lens number as the welding current increases.

b. Another fellow welder wants to know for sure that the correct lens is in the helmet. You could remind your friend that:

   (1) If after welding awhile your eyes feel okay, the lens is probably okay.
   (2) If after welding you see white spots or white blotches as after images, switch to a darker lens shade.
   (3) You should use the lens that gives you the best view of the arc and weld puddle.

Objective 14

Select true statements concerning protective clothing required for GTAW by placing an "X" next to the true statements.

_____ a. Shirts—Should be lightweight and have short sleeves so the welder will remain cool

_____ b. Pants—Should not have cuffs and should be long enough to come down over shoe/boot tops

_____ c. Welding caps—Should be worn to protect hair from sparks and spatter and should have a flexible bill that can be slipped around to cover either ear and keep sparks or metal spatter out of the ear opening

_____ d. Boots—Should be made of canvas with uppers that reach above the ankle to help prevent burns from sparks and spatter

_____ e. Gloves—Should be made of lightweight leather and designed especially for GTAW

_____ f. Jackets and aprons—Jackets and aprons made of leather should be worn for additional protection, especially when welding out of position or in confined areas where flying sparks present an increased hazard.

_____ g. Safety glasses—Should have metal frames and only need to be worn when grinding

_____ h. Face shield—Should wear a clear-plastic type of face shield to provide good visibility when grinding or sanding base metals for GTAW

Objective 15

Complete statements concerning environmental safety requirements by circling the material that best completes each of the following statements.

a. Ventilation—Many welding activities produce **(smoke) (toxic fumes)** and vapors that are hazardous to breathe, and every workstation should be equipped with a ventilation or exhaust system capable of safely removing dangerous and irritating smoke and contaminants.

b. Respirators—In confined areas where the hazard of toxic fumes is increased, a welder should wear an air-supplied respirator or a self-contained breathing apparatus, not a filter-type mask that cannot compensate for **(oxygen displacement) (smokey air)**.

c. Noise—This is a workplace hazard frequently overlooked, but earplugs or muffler-type ear protectors should be worn when the work area subjects a welder to high noise levels, especially high noise levels that are **(continuous) (irritating)**.

d. Lighting—Lighting in a work area or at a workstation should be bright enough to provide good visibility free of glare because poorly lit work areas contribute to eye fatigue, irritation, and **(poor work) (general health problems)**.

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

a. 4
b. 5
c. 3
d. 11
e. 10
f. 6
g. 1
h. 9
i. 8
j. 2
k. 7

Objective 2

b, c, e, f

Objective 3

a, c

Objective 4

a. Nonconsumable
b. Gas
c. Shielding gas

Objective 5

a. In all
b. Thicknesses
c. Heat
d. Ferrous and nonferrous

Objective 6

a. Nonconsumable, gases
b. Eye-hand coordination
c. Better jobs and higher pay

Objective 7

b, c, e, f, g, i

Objective 8

a. 2
b. 3

Objective 9

a, c, d, f, g, h, i

Objective 10

a

Objective 11

a. Radiation
b. Radiation, blister
c. Shielded

Objective 12

a. Fixed
b. Clear-glass or plastic
c. Clear to dark

Answers to Written Test

Objective 13	a. 3 b. 2
Objective 14	b, c, e, f, h
Objective 15	a. Toxic fumes b. Oxygen displacement c. Continuous d. Poor work

Unit 2 GTAW Equipment, Applications, and Techniques

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*Job Sheets

1—Set Up a Flow Meter Regulator for GTAW Shielding Gases . . . 3
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3—Prepare Mild or Stainless Steel for GTAW 7
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10—Weld to Specifications a Fillet Weld Lap Joint on Mild or Stainless Steel in the Horizontal Position 31
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15—Weld to Specifications a Fillet Weld Lap Joint on Mild or Stainless Steel in the Overhead Position 51
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17—Set Up and Shut Down GTAW Equipment for Welding Aluminum 59
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20—Strike and Maintain an Arc to Make Stringer Beads on Aluminum Without Filler Metal in the Flat Position 65
21—Strike and Maintain an Arc to Make Stringer Beads on Aluminum With Filler Metal in the Flat Position 69
22—Weld to Specifications a Fillet Weld Lap Joint on Aluminum in the Flat Position 73
23—Weld to Specifications a Fillet Weld T-Joint on Aluminum in the Flat Position 77
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26—Weld to Specifications a Fillet Weld T-Joint on Aluminum in the Horizontal Position 89
27—Weld to Specifications a Fillet Weld Lap Joint on Aluminum in the Vertical Position 93
28—Weld to Specifications a Fillet Weld T-Joint on Aluminum in the Vertical Position 97
29—Weld to Specifications a Square-Groove Butt Joint on Aluminum in the Vertical Position 101
30—Weld to Specifications a Fillet Weld Lap Joint on Aluminum in the Overhead Position 105
31—Weld to Specifications a Fillet Weld T-Joint on Aluminum in the Overhead Position 109

*The Job Sheets are located in the Student Workbook.

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Suggested Activities

Teaching Suggestions

- Discuss area shops or manufacturers who use gas tungsten arc welding in their production. Invite owners or supervisors to talk to the class about job opportunities for welders with GTAW skills.
- Impress upon students the problems posed by contamination in GTAW, not only with the electrode preparation and use, but in all stages of the process, especially improper welding environments.
- Take special care with Objectives 15, 16, and 17. Explain the need for careful electrode preparation for both DC and AC welding. Demonstrate how to taper a point and the importance of using a grinding wheel that will not contaminate the electrode.
- When discussing Objective 19, refer to Student Supplement 1 for more information on filler metals.
- Demonstrate the use of a filler rod as presented in Objective 22. Stress the importance of not removing the filler rod from the shielded zone during the welding process.
- Encourage students to reference the student supplements during training. Student Supplement 2 should help students better evaluate their abilities with GTAW, and Student Supplement 3 is vital for troubleshooting both machine and process problems.
- You may choose to combine the job sheets or demonstrate more than one job sheet at a time. If you do, please modify the Learning Activities Sheet as applicable.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

Sample A

4—**Skilled**—Can perform job with no additional training.
3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
1—**Unskilled**—Is familiar with process, but is unable to perform job.
0—**No exposure**—No information or practice provided during training program.

Sample B

Yes—Can perform job with no additional training.
No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Connor, Leonard, P., ed. *Welding Technology, Welding Handbook*, 8th ed. Vol. 1. Miami, FL: American Welding Society, 1987.
- *GTAW Manual*. Cleveland, OH: The Lincoln Electric Company.
- *New Lessons in Arc Welding* Cleveland, OH: The Lincoln Electric Company.
- O'Brien, R.L., ed. *Welding Processes, Welding Handbook*. 8th ed. Vol. 2. Miami, FL: American Welding Society, 1991.
- *The Procedure Handbook of Arc Welding*. 13th ed. Cleveland, OH: The Lincoln Electric Company, 1994.
- *2000 Lincoln Global Inc.* Cleveland, OH: The Lincoln Electric Company, 2000.
- *The Wheels of Learning—GTAW Equipment and Filler Metals*. Rosslyn, VA: National Center for Construction Education and Research, 2000.

Suggested Activities

Suggested Supplemental Resources

Print Media

- *GTAW (TIG)*—This book covers the fundamentals of the GTAW process as well as information on techniques used to produce a good weld. This illustrated text contains a wide range of information on joint design, weld symbols, weld defects, troubleshooting, and safety. Available from:

  Miller Electric Manufacturing Co.
  1635 W. Spencer St.
  P.O. Box 1079
  Appleton, WI 54912-1079
  920.734.9821
  www.millerwelds.com

Electronic Media

- Videos
  - *Gas Tungsten Arc Welding* (C00813)—This video shows how to set up a GTAW welder, assess current and amperage, and adjust gas flow. Procedures and weld demonstrations include maintaining a puddle, stringer beads, butt weld, T-weld, outside corner and multipass fillet. Available from:

    MAVCC at www.mavcc.org, or call 800.654.3988
  - *TIG Welding for Advanced* (NIM-CC-15-V92)—Recaps AC welding theory, HF spark unit, inherent rectification, and DC suppression. Demonstrates welding run on aluminum using AC. (11 min.) Available from:

    NIMCO
    102 Hwy. 81 North
    P.O. Box 9
    Calhoun, KY 42327-0009
    800.962.6662
    www.nimcoinc.com
  - *Gas Tungsten Arc Welding* (F53)—In this 4-part program student welders will see what GTAW is and how it operates as well as learn some basic exercises to help them get started. Close-up arc shots demonstrate key welding techniques for both beginners and welders who are developing their skills. The four videos cover welding with mild steel, stainless steel, and aluminum. ISBN 0-8064-1592-4. Available from:

    Delmar Publishing
    3 Columbia Circle
    P.O. Box 15015
    Albany, NY 12212-5015
    800.347.7707
    www.delmar.com

- *Introduction to Welding: Gas Tungsten Arc Welding*—This video explains how TIG welding differs from other types of welding. Electrode leads, hoses, regulators and collets are demonstrated as well as the use of the post flow timer to protect the weld from contamination. (12 min.) Available from:

  Glencoe/McGraw-Hill
  P.O. Box 508
  Columbus, OH 43216
  800.334.7344
  www.glencoe.com

- *GTAW Set-up Procedures*—This video contains a detailed demonstration on preparing your equipment for TIG welding as well as an in depth discussion of tungsten and gases. (13 min.) Available from:

  Miller Electric Manufacturing Co.
  1635 W. Spencer St.
  P.O. Box 1079
  Appleton, WI 54912-1079
  920.734.9821
  www.millerwelds.com

- CD-ROMs

  - *Gas Tungsten Arc Welding*—This CD consists of six segments that cover the following: introduction to GTAW; GTAW safety issues; equipment orientation; and welding in flat, vertical, horizontal, and overhead positions on mild steel, stainless steel, and aluminum. CDs are available in Spanish and English. Available from:

    Storck Interactive Training, Inc.
    P.O. Box 349
    4345 Highway 33 W
    West Bend, WI 53095
    262.335.9796

  - *TIG Fundamentals*—This CD covers system components, process fundamentals, electrical theory, safety, and power source operation. Available from:

    Miller Electric Manufacturing Co.
    1635 W. Spencer St.
    P.O. Box 1079
    Appleton, WI 54912-1079
    920.734.9821
    www.millerwelds.com

Written Test

Name ______________________________

Date ______________________ Score __________

Objective 1

Match the terms with their definitions.

1. Amps
2. Ar
3. Balanced wave
4. Cfh
5. EWP
6. EWTh
7. EWZr
8. He
9. Laminar flow
10. Pulsed gas tungsten arc welding
11. Unbalanced wave
12. Volts

_____ a. The abbreviation for helium shielding gas

_____ b. A tungsten electrode with 1% or 2% thoria added to give it greater current carrying capacity, longer life, and greater resistance to contamination

_____ c. A tungsten electrode with some zirconium oxide added to give it better performance characteristics in certain types of AC welding

_____ d. The abbreviation for argon shielding gas

_____ e. A long, streamlined flow of shielding gas used to control turbulence around a weld puddle

_____ f. The amount of current or rate of electron flow in a welding circuit

_____ g. The amount of force required to force a current through a given resistance in a welding circuit

_____ h. A high frequency AC welding machine power configuration that has negative and positive current roughly equal or balanced

_____ i. A gas tungsten arc welding process variation in which the current is pulsed

_____ j. A tungsten electrode of 99.5% purity which has a relatively low current carrying capacity with AC power and a low resistance to contamination

_____ k. The standard by which the flow rate of shielding gases is measured

_____ l. A high frequency AC welding machine power configuration that has either the negative or positive current stronger or unbalanced

Written Test

Objective 2

Match GTAW machine controls with their functions.

1. Current range selector
2. Fine adjustment current control
3. High frequency
4. High frequency intensity rheostat
5. High frequency switch
6. Polarity switch
7. Post flow
8. Power on-off switch
9. Remote control switch
10. Start adjustment control (soft-start switch)
11. Weld control switch

_____ a. Provides quick adjustment for desired polarity, DCEP, AC, and DCEN, and should never be changed while welding

_____ b. Provides adjustment of intensity for start only or continuous operation

_____ c. Provides a specific amperage selection from minimum to high in low range, minimum to high in medium range, etc.

_____ d. Functions as a pilot arc to bridge the gap between the electrode and base metal and eliminates the need to scratch start the arc

_____ e. Provides SMAW or GTAW welding source

_____ f. Provides basic power input or shut-off for entire welding machine

_____ g. Functions to permit shielding gases to continue flowing around the electrode after the arc is extinguished to eliminate contamination of the electrode and the weld puddle as they cool

_____ h. Reduces current during starting to help eliminate burning the tungsten electrodes or burning through thin gauge metals

_____ i. Turns high frequency on or off, provides high frequency for continuous operation with nonferrous metals or start only for ferrous metals

_____ j. Provides facility to switch to foot or hand operation or to panel operation

_____ k. Provides a general range of amperage selections such as low, medium, high, or maximum, and should never be changed while welding

Written Test

Objective 3

Complete statements concerning the concept of pulse current and its use in GTAW by circling the answer that best completes each of the following statements.

a. **(Some welding machines) (All GTAW machines)** have a special setting called "PULSE MODE" or "PULSE."

b. The pulse setting is used to regulate current so that it establishes **(an on-off) (a heat-cool)** pattern that is in timed segments or pulses.

c. The pulsing action **(maximizes heat input) (minimizes heat build-up)** in the base metals, especially thin base metals, and results in minimum distortion and better welds.

Objective 4

Differentiate between types of GTAW systems by placing an "X" in the blank next to the definition of an air cooled system.

_____ a. Usually suitable for light-duty welding that does not exceed 150 amps, but cannot be used for lengthy periods of continuous welding

_____ b. Required for heavy-duty continuous welding

Objective 5

Select true statements concerning cooling system safety by placing an "X" in the blanks next to the true statements.

_____ a. Some systems have a fail-safe device that will not allow the welding circuit to be completed until the cooling system is functioning at a required level.

_____ b. Some systems have water flow safety controls so that should the coolant supply diminish, the electrical power source is shut off.

_____ c. Some systems have clear plastic tubing built into the supply lines so the circulating liquid can be monitored visually by the operator.

_____ d. All systems should be checked during set-up and monitored periodically during operation to avoid damage to equipment.

Objective 6

Complete definitions of types of power cables and their characteristics by circling the answer that best completes each of the following statements.

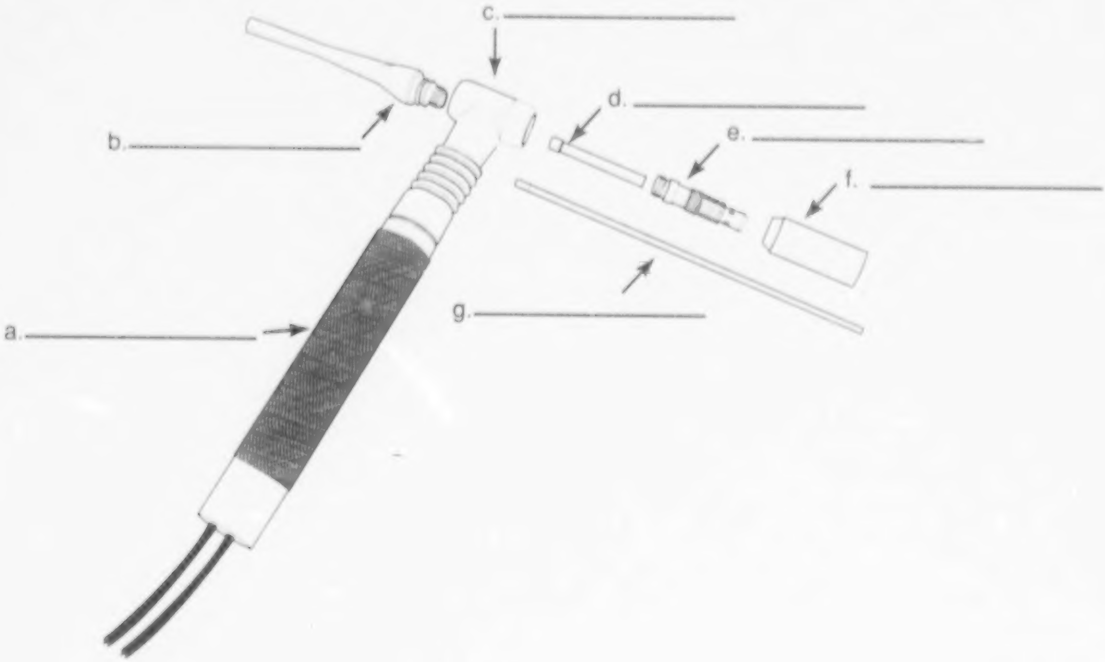
a. Air cooled—These types of cables have **(combined) (separate)** gas and electric lines encased in a single insulated cover.

b. Water cooled—These types of cables have separate gas and **(water-in) (electric)** lines and a **(torch cable) (water-out line)** and power cable that are separate but usually encased in a single insulated cover.

Written Test

Objective 7

Identify basic parts of a GTAW torch by writing the correct part name in the appropriate blank.



Objective 8

Complete statements concerning the gas lens and its uses by circling the correct answers.

a. A gas lens has a porous barrier diffuser with one or more fine mesh screens, and is designed to fit around the **(electrode or the collet) (nozzle)**.

b. A gas lens produces a longer, undisturbed flow of shielding gas, a phenomena called **("laminar flow") ("lens shielding")**.

c. With a gas lens, an operator can weld with the nozzle **(three inches) (an inch or more)** away from the work, and improve the ability to see the weld pool.

d. Better sight of the weld pool means that an operator has better control working on inside corners or other areas **(with limited access) (on overhead welds)**.

Objective 9

Match types of nozzles with their functions.

1. Alumina fused quartz
2. Ceramic
3. Fused quartz
4. Metal

_____ a. Most commonly used nozzle because it does an adequate job and is the least expensive

_____ b. A clear-glass nozzle that allows a welder to see through it when good visibility of the weld zone is required

_____ c. Made of high-strength aluminum to give high impact resistance and long life

_____ d. Usually copper and used where application might break other types of nozzles

Objective 10

Arrange in order the steps in GTAW nozzle selection by placing a "1" beside the first step, and arrange the other steps in order.

_____ a. Use the amperage setting to determine the proper electrode diameter for the job.

_____ b. Use the electrode diameter to select the proper gas nozzle, and remember that the gas nozzle size is based on the inside diameter of the nozzle.

_____ c. Determine the type of current, DCEN, DCEP, or AC, and the amperage setting you need for the job.

Objective 11

Select true statements concerning GTAW shielding gases and their characteristics by placing an "X" in the blanks next to the true statements.

Note: For a statement to be true, all parts of the statements must be true.

_____ a. Argon

- Produces smoother, quieter arc
- Has greater cleaning action on AC
- Is less abundant
- Costs more
- Can use lower flow rates
- Has better resistance to cross drafts

_____ b. Helium

- Has a smaller heat affected zone
- Has hotter arc than with argon (1.7 times)
- He and Ar/He mixtures are recommended for thick sections and materials having high melting temperatures
- Provides higher welding speeds

_____ c. Hydrogen (when added to argon)

- Constricts the arc further
- Provides cleaner welds
- Provides faster travel speeds
- Deeper depth to width ratio
- Used primarily for welding austenitic stainless steels and some nickel alloys

_____ d. Nitrogen

- Produces more energy to the work
- Excellent for welding copper

Objective 12

Select true statements concerning flow meter design and use by placing an "X" in the blanks next to the true statements.

_____ a. Flow meters regulate the flow of low pressure gases as measured in cubic feet per hour.

_____ b. Operate floating-ball type flow meters only in the horizontal position.

_____ c. Always use a regulator between the gas supply and the flow meter to assure uniform input pressure to the flow meter.

_____ d. Close the adjusting screw when first setting up a gas supply, and then turn it on slowly to make the proper cfh adjustment.

Objective 13

Complete statements concerning flow rates for GTAW shielding gases by circling the correct answers.

a. Flow rates for GTAW shielding gases vary with the type of gas, the nozzle size, and **(contaminants) (air movement)** in the welding environment.

b. With argon as a shielding gas, **(30) (20)** cfh is an almost standard flow rate for DCEN and AC welding.

c. In general, flow rate increases in proportion to the cross-sectional area at the nozzle; this means that some flow rates could range as high as **(45) (35)** cfh or as low as **(5) (15)** cfh.

d. Excessive flow rates contribute to **(bad visibility) (turbulence)** around the weld puddle and usually cause weld problems.

e. Flow rate usually has to be **(increased) (decreased)** when welding in the overhead position.

Objective 14

Complete the chart concerning tungsten electrodes, their characteristics and applications by writing the correct answers in the appropriate blanks.

Type of Electrode	AWS	Color	Polarity	Applications
a. ______	EWP	Green	AC	Aluminum, copper, and magnesium alloys
1% Thoriated	EWTh-1	b. ______	DC-	Aluminum, copper, magnesium alloys, nickel, plain carbon and low alloy steels, stainless steel, and titanium
2% Thoriated	c. ______	Red	DC-	Aluminum, copper, magnesium alloys, nickel, plain carbon and low alloy steels, stainless steel, and titanium
d. ______	EWZr	Brown	AC	Aluminum, copper and its alloys, magnesium alloys
Ceriated	EWCe-2	e. ______	AC & DC-	Aluminum, copper, and magnesium alloys
Lanthanated	EWLa-1	Black	AC & DC-	Aluminum, copper, and magnesium alloys
Lanthanated	EWLa-1.5	Gold	f. ______	Aluminum, copper, magnesium alloys, nickel, plain carbon and low alloy steels, stainless steel, and titanium
Lanthanated	g. ______	Blue	AC & DC-	Aluminum, copper, magnesium alloys, nickel, plain carbon and low alloy steels, stainless steel, and titanium
h. ______	EWG	Gray	AC & DC-	Aluminum, copper, magnesium alloys, nickel, plain carbon and low alloy steels, stainless steel, and titanium

Written Test

Objective 15

Select true statements concerning guidelines for preparing tungsten electrodes for DC welding by placing an "X" in the blanks next to the true statements.

_____ a. For DC welding on very thin metal or when using low-amperage starting, grind a tungsten electrode on a taper to a conical tip.

_____ b. If there is a chance that a fine point might melt off into the weld deposit, do not taper the electrode.

_____ c. Grind the taper so that it is equal in length to 2 to 2 1/2 times the diameter of the electrode.

Objective 16

Complete statements concerning guidelines for grinding electrodes for DC welding by circling the correct answers.

a. Grind tungsten electrodes on a grinding wheel reserved especially for use with tungsten in order to avoid **(electrode waste) (contamination)**.

b. For best results, use a **(90-grit) (120-grit)** grinding wheel.

c. Grind the tungsten electrode **(crosswise over) (lengthwise with)** the grain of the electrode, not **(lengthwise with) (crosswise over)** the grain because that will restrict current flow and cause other welding problems.

d. Position the tungsten **(above) (below)** the wheel at an angle that permits consistent shaping without chance that the grinding surface could catch the electrode and ruin the end.

Objective 17

Solve problems concerning guidelines for preparing electrodes for AC welding by circling the number of the item that best solves each of the following problems.

a. A fellow welder is trying to form the ball tip on a thoriated tungsten electrode by striking it on the aluminum workpiece. The welder should know that:

(1) It is exactly the way it should be done.
(2) A thoriated tungsten electrode should be struck on a piece of copper to form the ball end.
(3) A thoriated tungsten electrode should be tapered before attempting to form the ball end.

b. You notice a fellow welder trying to form the ball end on a thoriated tungsten electrode with the machine set on a high amperage and straight polarity. If you wanted to help your friend, you could:

(1) Remind the welder that the electrode needs proper tapering.
(2) Remind the welder to lower the amperage setting.
(3) Remind the welder to lower the amperage setting, use reverse (DCEP) polarity, and make sure the high frequency control is on "start only."

c. You notice another welder trying to form the ball end on a pure tungsten electrode that has a $^1/_4$" diameter. The ball does not form properly, but the welder insists that a pure tungsten electrode should form the proper ball end during the welding process. You could help by:

(1) Reminding the welder that larger diameter electrodes should be tapered even when the end will later be balled for AC welding.
(2) Reminding the welder to start the ball end on a copper block.
(3) Suggesting the welder use a smaller diameter electrode.

Objective 18

Select true statements concerning guidelines for GTAW electrode extension by placing an "X" in the blanks next to the true statements.

Note: For a statement to be true, all parts of the statement should be true.

_____ a. Several variables dictate how far a tungsten electrode should be extended from the nozzle:

- Type of welding, DCEN, DCEP, or AC
- Metal thickness
- Joint design
- Welding position

_____ b. One general rule is to make electrode extension as long as possible to improve shielding.

_____ c. Another general rule is that proper electrode extension should give good penetration and shielding, and still provide the operator with a functional view of the weld puddle.

_____ d. Fillet welds almost always require a shorter electrode extension than butt welds.

_____ e. Develop the habit of starting with an electrode extension of about $^1/_2$" and then adjusting the extension as welding continues.

Objective 19

Select true statements concerning guidelines for filler metal selection and use by placing an "X" in the blanks next to the true statements.

_____ a. Select a filler metal that is compatible with the joint design.

_____ b. Select the type and size of filler metal according to the type and thickness of the base metal.

_____ c. Keep filler metals clean and free of contamination whether in use or in storage.

_____ d. Do not remove the hot end of the filler wire or rod from the protection of the gas-shielded zone during the welding operation.

Written Test

Objective 20

Complete statements concerning requirements for base metal preparation by circling the correct answers.

a. Remove mill scale, dirt, and paint from all surfaces with a **(wire brush) (sander/grinder)**.

b. Remove normal surface oxides with a **(wire brush) (stainless steel brush)**.

c. Remove heavy oxides, grease, and oil with a shop rag wet with a combination cleaner that will **(degrease and deoxidize) (clean and remove paint)** at the same time.

d. If you use solvents for cleaning, **(weld immediately after cleaning) (allow them to dry before welding starts)**.

e. Fit-up is critical in GTAW, so make joint preparation uniform with **(minimum) (no)** irregularities or gaps.

f. Begin welding as soon as possible after the base metal has been prepared to eliminate the chance of **(airborne contaminants) (dust)** adhering to the metal.

Objective 21

Select true statements concerning special problems with contamination and air movement by placing an "X" in the blanks next to the true statements.

_____ a. Metals that are not properly cleaned before welding may not contaminate a tungsten electrode, but the potential for contamination is present.

_____ b. Work areas that are unclean will add to the potential for contaminants to slow or stop the welding process.

_____ c. Air movement across the weld zone blows the shielding gas away and contributes to immediate contamination of the weld zone.

_____ d. Work areas should be checked for drafts and cross ventilation that could blow shielding gas away, and screens or deflectors should be erected around the work area as needed.

Objective 22

Arrange in order the steps for manual welding with a filler rod by placing a "1" next to the first step, and arrange the following steps in order.

_____ a. Move torch back to the leading edge of the puddle and repeat the procedure.

_____ b. Move the torch back from the puddle away from the direction of travel and angle it at 75–80°.

_____ c. Select and prepare tungsten electrode, adjust electrode extension, and adjust machine controls.

_____ d. Move the torch so that tungsten electrode comes within 1/8" to 1/16" of the base metal, strike arc and adjust to desired length.

_____ e. Withdraw the filler rod from the puddle, but be sure to keep the end of the rod in the shielded zone.

_____ f. Hold the torch at a 15–20° angle to the base metal and make very slight circular motions until a bright, fluid puddle forms.

_____ g. Insert the filler metal rod at a 10–20° angle into the leading edge of the molten pool and let a drop or two of molten metal fill the puddle.

Objective 23

Select true statements concerning backup bars and their use in GTAW by placing an "X" next to the true statements.

_____ a. On certain GTAW applications, backup bars (usually copper) may be required to physically support the joint and the weld puddle.

_____ b. Backup bars also serve to protect the backside of a weld from contamination and to "chill" or draw heat away from the weld zone.

_____ c. In pipe welds and groove welds, welded from one side only, a purging gas should be directed to protect the back side of the weld from contamination.

Objective 24

Complete statements concerning guidelines for troubleshooting GTAW problems by circling the correct answers.

a. Try to isolate electrical or mechanical problems from **(process) (workplace)** problems.

b. Check the workplace for air movement or drafts that could be causing problems with **(shielding) (contamination)**.

c. Change only one variable at a time so you can use a logical process of **(isolation) (elimination)** instead of creating a totally different problem.

d. Observe all safety rules when troubleshooting, especially when troubleshooting **(system) (electrical)** problems.

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

a. 8
b. 6
c. 7
d. 2
e. 9
f. 1
g. 12
h. 3
i. 10
j. 5
k. 4
l. 11

Objective 2

a. 6
b. 4
c. 2
d. 3
e. 11
f. 8
g. 7
h. 10
i. 5
j. 9
k. 1

Objective 3

a. Some welding machines
b. A heat-cool
c. Minimizes heat build-up

Objective 4

a

Objective 5

a, b, c, d

Objective 6

a. Separate
b. Water-in, water-out line

Objective 7

a. Handle
b. Back cap
c. Torch body
d. Collet
e. Collet body
f. Nozzle
g. Electrode

Objective 8

a. Electrode or the collet
b. "Laminar flow"
c. An inch or more
d. With limited access

Objective 9

a. 2
b. 3
c. 1
d. 4

Objective 10

a. 2
b. 3
c. 1

Answers to Written Test

Objective 11	b, c, d
Objective 12	a, c, d
Objective 13	a. Air movement b. 20 c. 35, 15 d. Turbulence e. Increased
Objective 14	a. Pure b. Yellow c. EWTh-2 d. Zirconiated e. Orange f. AC & DC- g. EWLa-2 h. Rare earths
Objective 15	a, c
Objective 16	a. Contamination b. 120-grit c. Lengthwise with, crosswise over d. Above
Objective 17	a. 2 b. 3 c. 1
Objective 18	a, c
Objective 19	b, c, d
Objective 20	a. Sander/grinder b. Stainless steel brush c. Degrease and deoxidize d. Allow them to dry before welding starts e. No f. Airborne contaminants
Objective 21	b, c, d

Answers to Written Test

Objective 22

a. 7
b. 4
c. 1
d. 2
e. 6
f. 3
g. 5

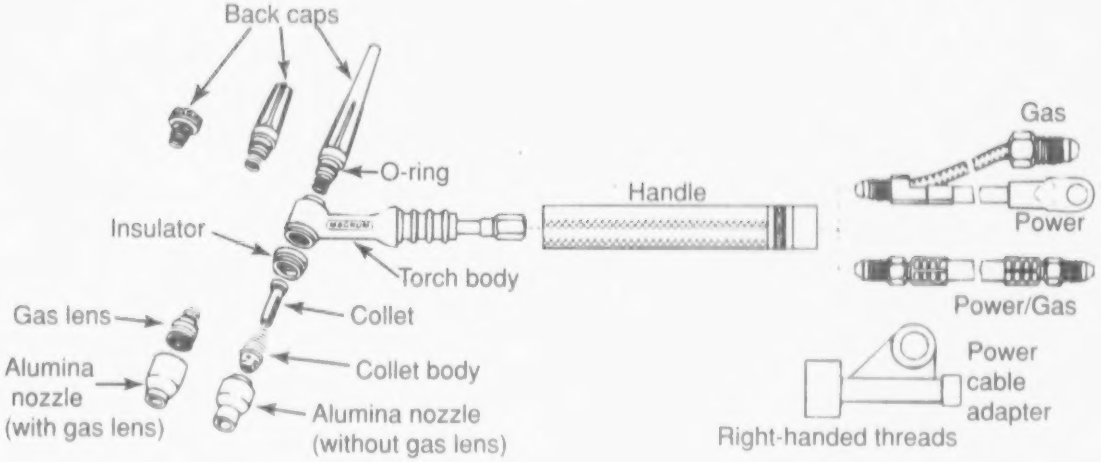
Objective 23

a, b, c

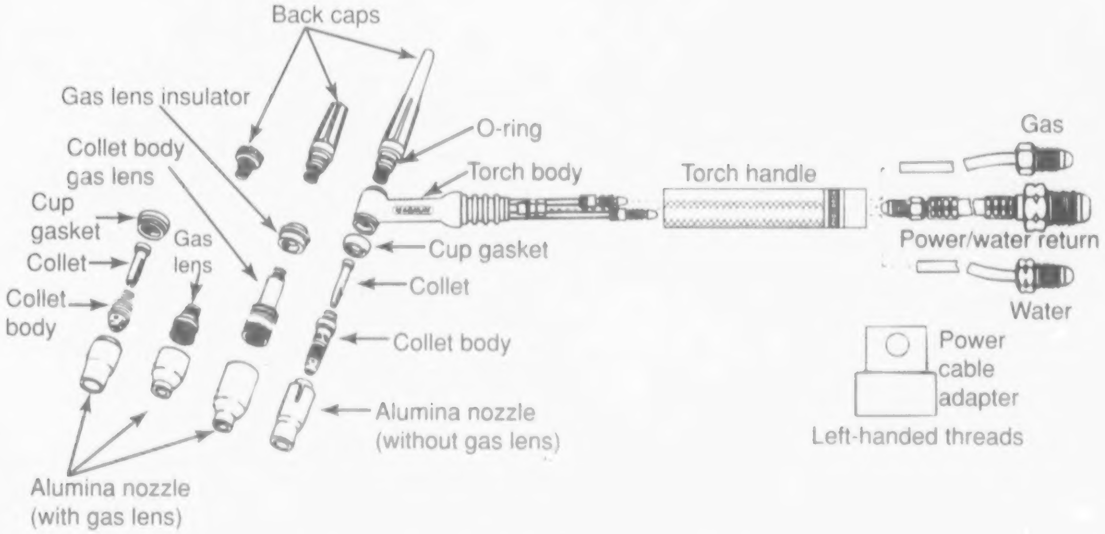
Objective 24

a. Process
b. Shielding
c. Elimination
d. Electrical

Power Cables


Back caps
O-ring
Insulator
Torch body
Handle
Gas
Power
Power/Gas
Gas lens
Collet
Collet body
Alumina nozzle (with gas lens)
Alumina nozzle (without gas lens)
Power cable adapter
Right-handed threads

Air-Cooled Power Cable

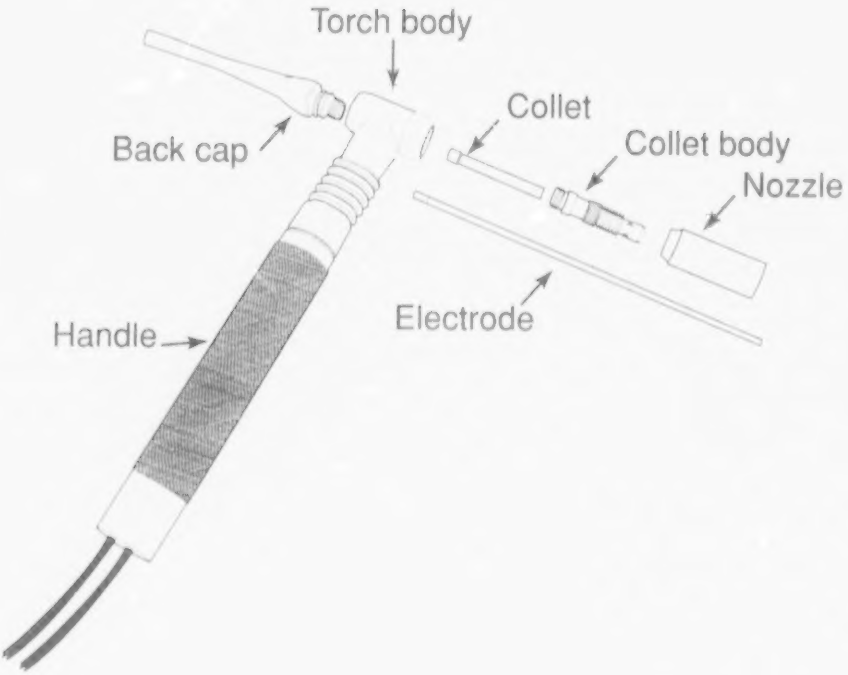

Back caps
Gas lens insulator
O-ring
Collet body gas lens
Torch body
Torch handle
Gas
Cup gasket
Gas lens
Collet
Collet body
Cup gasket
Collet
Power/water return
Water
Collet body
Power cable adapter
Alumina nozzle (without gas lens)
Left-handed threads
Alumina nozzle (with gas lens)

Water-Cooled Power Cable

Courtesy of Lincoln Electric Company.

TM 1

GTAW Torch


Torch body
Back cap
Collet
Collet body
Nozzle
Electrode
Handle

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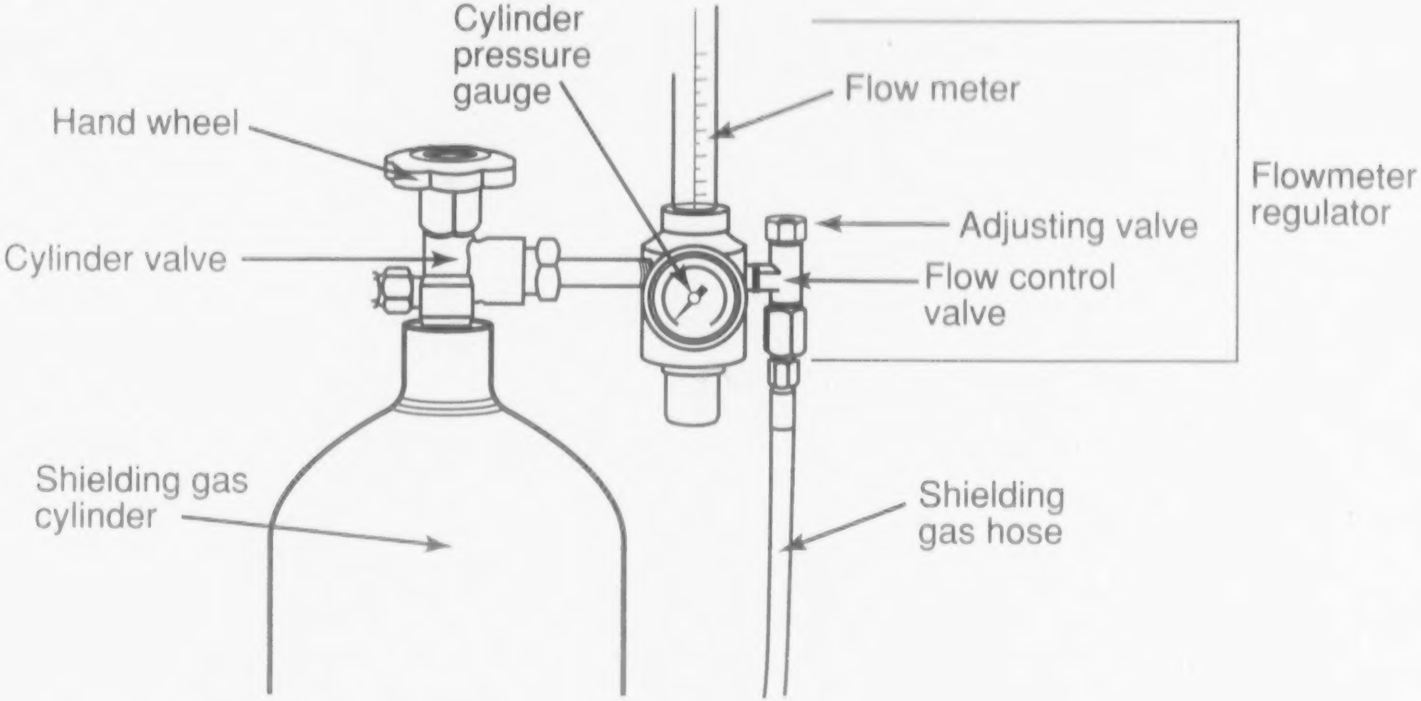
Flow Meter


Cylinder pressure gauge
Hand wheel
Flow meter
Flowmeter regulator
Cylinder valve
Adjusting valve
Flow control valve
Shielding gas cylinder
Shielding gas hose

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Unit 3 Plasma Arc Cutting

Unit Contents

Teacher Components

Teacher Page

Suggested Activities 3–3
Written Test 3–7
Answers to Written Test 3–19

Teacher Supplement

1—Water Cutting With PAC Systems 3–21

Transparency Master

1—Plasma Arc Cutting 3–23

Student Components

Student Page

Learning Activities Sheet 3–3
Objective Sheet 3–5
Information Sheet 3–7

*Job Sheets

1—Prepare a PAC Machine for Operation 113
2—Complete a Contact Cut on Selected Metal 115
3—Complete a Stand-Off Cut on Selected Metal 117
4—Gouge Mild Steel Plate With a PAC Unit 119

*The Job Sheets are located in the Student Workbook.

/

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom.
- Make copies of any teacher supplements that will be provided for each student.
- Make a transparency from the transparency master included in this unit. This appears in the teacher edition only.

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.

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Suggested Activities

- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Use Objective 2 to illustrate the concept of the fourth state of matter and how high energy plasma functions in the plasma arc cutting process.
- Modify Objective 3 as required to reflect components of the system students will actually be working with. The unit presents three different PAC systems, but other systems may have component variations.
- Objectives 4, 5, and 6 require special attention because they concern safety. With a PAC system, safety requirements exceed those of other welding/cutting processes. The noise factor is especially important because even low amperage systems which may modify noise to a degree are still noisy enough to contribute to hearing problems for those exposed to the noise for extended periods of time. Fumes are another problem with PAC. Impress students with all the parameters of PAC safety, not just electrical safety requirement.
- When discussing nozzle selection in Objective 10, discuss the structure of the nozzle and the important part it plays in swirling the gas around the electrode to accelerate the ionization process. Also note that some manufacturers use a "swirl" ring as a torch component to further accelerate ionization.
- Stress the importance of clean, dry, oil-free air when using compressed shop air with a dual-flow PAC system. Demonstrate how to purge or clean the sediment bowl during the setup procedure for cutting.
- Demonstrate gouging, piercing, and beveling. If students have time, permit them to practice piercing and beveling as part of Job Sheet 4.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

Sample A

4—**Skilled**—Can perform job with no additional training.
3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
1—**Unskilled**—Is familiar with process, but is unable to perform job.
0—**No exposure**—No information or practice provided during training program.

Sample B

Yes—Can perform job with no additional training.
No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- *A History of Plasma Cutting Milestones in the Development of a New Technology.* Hanover, NH: Hypertherm, Inc., 1991.
- Connor, Leonard, P., ed. *Welding Technology. Welding Handbook*, 8th ed. Vol. 1. Miami, FL: American Welding Society, 1987.
- *Instructional Manual for the Thermal Arc® PAK® 5XR™* St Louis, MO: Thermal Dynamics Corporation.
- O'Brien, R.L., ed. *Welding Processes. Welding Handbook.* 8th ed. Vol. 2. Miami, FL: American Welding Society, 1991.
- *Smith Plasma Cutting Systems Owners Manual for SPC50A, SPC80A, and SPC120A-4.* Watertown, SD: Smith Equipment, Division of Tescom Corporation.

Suggested Activities

Suggested Supplemental Resources

Print Media

- *Plasma Arc Welding* poster (Item no. EW-480) is available from:

  Hobart Institute of Welding Technology
  400 Trade Square East
  Troy, OH 45373
  800.332.9448
  www.welding.org

- *Recommended Practices for Plasma Arc Cutting* is a basic process reference that is also approved by ANSI. Available from:

  American Welding Society
  550 N.W. LeJeune Road
  Miami, FL 33126
  800.443.9353
  www.aws.org

Electronic Media

- Videos

  — *Health Factors in Welding Operations* (28 min.)—Excellent program for welders. Explains a variety of precautions, possible health problems involved in welding operations, and tips on how to generally improve the employee's health. 1001H

  — *Hearing Conservation* (11 min.)—This video heightens awareness of hearing conservation in the workplace. Explains the anatomy of the ear, how noise can cause hearing loss, and how to prevent hearing loss. 1012B (English & Spanish)

  — *Eye Protection A New Approach* (Humorous Program, 16 min.)—This program explains eye protection requirements in a humorous manner. 1003B (English)

  The videos listed above are available from MAVCC at www.mavcc.org, or call 800.654.3988. Most videos are also available in CD-ROM format.

  — *Plasma Cutting & Gouging*—This video describes the plasma process and gives you practical "how - to" information. Equipment setup, consumable needs and care, and setting the machine for cutting are covered. Steps you through cutting and gouging procedures for steel, stainless, and aluminum. Available from:

  Miller Electric Manufacturing Co.
  1635 W. Spencer St.
  P.O. Box 1079
  Appleton, WI 54912-1079
  920.734.9821
  www.millerwelds.com

Written Test

Name ____

Date ______________________________ Score __________

Objective 1

Match the terms with their definitions.

1. Cfh
2. CNC
3. Consumables
4. Contact cutting
5. Hafnium
6. Pilot arc
7. Plasma arc
8. Safety interlocks
9. Scfh
10. Stand-off cutting
11. Trigger switch

_____ a. A metallic element in PAC electrodes that are used for cutting with air or oxygen

_____ b. The arc initiated *inside* a PAC torch when a cutting gas encounters electrical energy in a nozzle

_____ c. Materials or components that are used up during a process

_____ d. A hand cutting technique that requires holding a torch at a slight angle and keeping the torch in contact with the workpiece as a cut is made

_____ e. The switch or button on a PAC torch that initiates the flow of cutting gas into a plasma arc nozzle

_____ f. The measurement of flow in an environment where temperature and pressure are held to standards of temperature and pressure

_____ g. The measurement of flow in an environment where temperature and pressure are not held to a standard

_____ h. A hand or machine cutting technique in which the plasma torch is held perpendicular to and about 1/8" above the workpiece as the cut is made

_____ i. Control devices that shut off a plasma torch when cutting air falls below a minimum pressure or when torch or machine components overheat

_____ j. Machines that have high travel speeds required to produce good quality cuts and have a high volume of production; operator can input instructions such as speed, current, gas flow, location and shape of part to be cut

_____ k. The arc created *outside* a PAC torch between the nozzle and the workpiece

Written Test

Objective 2

Complete statements concerning the basic characteristics of plasma arc cutting by circling the material that best completes each of the following statements.

a. The "plasma" in plasma arc cutting is formed when constricted shop air or gas flows through the arc of a **(stainless steel) (high temperature)** electrode.

b. The plasma becomes **("ionized") ("super heated")** or electrically conductive and transfers a high temperature electric arc through a nozzle to a workpiece.

c. When the tip of a plasma arc torch is brought close to or in contact with a workpiece, the plasma stream produces a stiff, **(constricted) (gaseous)** cutting arc.

d. The orifice in the torch nozzle directs the plasma stream to the workpiece where it superheats a small area of the workpiece to a temperature so high that cutting can begin with **(no preheating) (minimal preheating)**.

e. As the arc melts the workpiece, the **(high-velocity) (high-temperature)** jet blows away molten metal to form the kerf or cut.

Objective 3

Match basic components with their functions in an air cut PAC system.

1. Filter assembly
2. PAC machine
3. Regulator assembly
4. Torch
5. Torch lead assembly

_____ a. A three-lead cable used to connect the torch to a gas supply, a power source, and a torch trigger interface

_____ b. A handheld device which houses the torch head, the electrode, cutting nozzle, shield cup, and trigger switch

_____ c. An assembly that filters compressed shop air so that it will be free of oil and water

_____ d. An assembly that contains the pressure regulator for adjusting shop air in p.s.i. (pounds per square inch)

_____ e. A portable wheel-mounted control cabinet housing electrical components, pressure safety control, electrical overload control, and an air valve assembly

Objective 4

Select true statements concerning plasma arc electrical safety by placing an "X" in the blanks next to the true statements.

_____ a. A plasma arc system must not exceed the amperage ratings of the fuse or breaker of the source power supply.

_____ b. Since system power may vary from 150v to 400v, power leads into a PAC system have to be attached to the correct lugs to avoid erratic performance and possible damage to components.

_____ c. When using an extension cord with a PAC machine, make sure the cord has the proper wire gauge for its length.

_____ d. Always disconnect the power source from the PAC machine before making any internal adjustments or performing troubleshooting.

_____ e. Allow only your hands to come in contact with the workpiece when cutting with a PAC system.

Objective 5

Complete statements concerning plasma arc environmental safety by circling the material that best completes each of the following statements.

a. Moisture on human skin **(increases) (decreases)** electrical resistance and increases the potential for severe shock, so never use a plasma arc system in damp, wet areas.

b. Wear earplugs or muffs for protection when plasma arc cutting because the process produces **(high noise levels) (high frequency emissions)**.

c. Infrared/ultraviolet rays produced by the PAC process are hazardous, so always wear an approved filter lens, at least a number **(eight) (nine)** shade to protect your eyes.

d. Rays that pose danger to your eyes can also **(burn) (irritate)** your skin, and so can molten metal or sparks, so wear gloves, an apron, safety shoes, and safe clothing as the job requires.

e. Perform PAC in open, well **(lit) (ventilated)** areas, and always check confined areas for explosive and toxic gases before cutting starts.

f. Never cut in an area that contains combustible vapors, flammable liquids, or explosive dust, and NEVER cut into tanks or closed containers that have held **(hazardous materials) (cleaning supplies)**.

Written Test

Objective 6

Solve problems concerning plasma arc workplace safety guidelines by circling the number of the item that best solves each of the following problems.

a. Plasma arc cutting is taking place next to an old wooden structure. You should:

(1) Be extra careful.
(2) Erect a heat shield between the work area and the structure.
(3) Have someone stand by with a fire extinguisher.

b. Several small cans of volatile cleaning material are stored fairly close to a position where plasma arc cutting has to be performed. You should:

(1) Move the cleaning supplies to a safe area.
(2) Cover the cleaning supplies so sparks can't reach them.
(3) Erect a barrier of some kind.

c. You report for a PAC job and find the facility you'll be working in has an old, wooden floor. You should:

(1) Inform your supervisor that workplaces for plasma arc cutting should have a fireproof floor, and arrange for safe conditions.
(2) Cover the floor with something safe.
(3) Continue PAC cutting, but keep a fire extinguisher handy.

Objective 7

Select true statements concerning advantages of plasma arc cutting by placing an "X" in the blanks next to the true statements.

_____ a. PAC systems have extremely fast cutting speeds when compared to oxyfuel cutting, or sawing or grinding.

_____ b. Oxyfuel cutting is pretty much confined to carbon steels, but PAC works well with all ferrous and nonferrous metals that are electrically conductive.

_____ c. Because PAC requires no preheating, the cost of fuel gas is minimized and the cutting process is accelerated.

_____ d. No preheating combined with high speed minimize the heat-affected zone and helps control distortion.

_____ e. The cost of fuel gases can be eliminated because PAC can operate with air from a shop air compressor.

_____ f. PAC systems are highly portable and effectively used for indoor maintenance, but seldom used outside.

Objective 8

Select true statements concerning characteristics of plasma arc transfer modes by placing an "X" in the blanks next to the true statements.

_____ a. The plasma jet formed in a PAC torch can be operated in either the transferred mode or the nontransferred mode.

_____ b. In the nontransferred mode, the electric current first flows between the electrode and the torch nozzle and when the torch strikes or comes close to the workpiece, the arc transfers to the workpiece.

_____ c. In the transferred mode, the least used mode, the electric current flows directly between the electrode and the workpiece when the torch strikes or comes close to the workpiece.

_____ d. Some systems employ a pilot arc to initiate plasma transfer or to restart the arc automatically when electrical contact with the workpiece is interrupted.

_____ e. The pilot arc enables a plasma torch to cut through grating or expanded metal without the operator having to restart the torch time after time, and it also saves wear and tear on consumables.

_____ f. A high frequency pilot arc is used for applications where a torch has to cut through paint, rust, oil, and scale, a condition where the transferred mode could not be initiated.

Objective 9

Solve problems concerning guidelines for PAC electrode selection by circling the number of the item that best solves each of the following problems.

a. You are assigned a plasma arc cutting job which will use compressed air as a cutting gas. You should:

(1) Use a tungsten electrode because their low cost makes PAC a profitable cutting system.
(2) Use only a zirconiated electrode.
(3) Use a hafnium electrode because it will not deteriorate in air as will other types of electrodes.

b. You are on a PAC job that requires a change of metal thickness from a 1/16" plate to a 1/4" plate. You should:

(1) Definitely up the amperage on the PAC machine.
(2) Change to a recommended electrode before changing amperage range.
(3) Increase amperage and slow the cutting speed to compensate for the thicker metal.

Written Test

Objective 10

Select true statements concerning guidelines for cutting nozzle selection and installation by placing an "X" in the blanks next to the true statements.

_____ a. Just like electrodes, cutting nozzles are designed for specific amperage ranges; change to the recommended cutting nozzle before changing amperage range.

_____ b. A cutting nozzle is sized according to its length and the size is stamped or laser imprinted on the nozzle.

_____ c. Depending on the manufacturer, the orifice size may be stated in thousandths of an inch for smaller electrodes, fractions of an inch for larger electrodes, or millimeters.

_____ d. Always check the manufacturer's recommended orifice size for the power range, the type and thickness of metal being cut, and the recommended cutting speed.

_____ e. Change or install cutting nozzles with the proper tools, and tighten nozzles until they are really tight.

Objective 11

Solve problems concerning shielding cups, their design and uses by circling the number of the item that best solves each of the following problems.

a. You've been assigned a job that calls for stand-off cutting and have to select a shielding cup. You should:

(1) Look for a shield cup that has a taper with a smooth face so you can move the torch with ease.
(2) Look for a shield cup that has a taper with notches in the face to permit gas and fumes to escape while stand-off cutting.
(3) Select any cup available and simply adjust your cutting speed as required.

b. You've been asked to explain to a beginning student the difference between contact and stand-off cutting. Aside from explaining the distance required for stand-off cutting, you should:

(1) Explain the importance of cutting speed when stand-off cutting.
(2) Note that stand-off cutting is performed with the torch at a 45° angle to the workpiece.
(3) Note that stand-off cutting is performed with the torch at a 90° angle to the workpiece.

Objective 12

Select true statements concerning plasma air and secondary air used with PAC by placing an "X" in the blanks next to the true statements.

_____ a. The air that is fed into a PAC torch to be ionized and ejected to form the plasma that cuts through a workpiece is called plasma air or cutting air.

_____ b. The air that is fed into a PAC torch and channeled around the nozzle to provide cooling and help remove metal from the cut is called secondary air or shielding air.

_____ c. In PAC systems that use a coolant, the coolant takes the place of secondary air; the coolant is injected through the torch to help cool components and restrict the arc.

_____ d. Argon is a popular plasma or cutting gas with PAC systems, and is often used in combination with other gases for secondary air; air or oxygen for cutting mild steel, carbon dioxide for cutting stainless steel, and argon/hydrogen for cutting aluminum.

_____ e. The plasma air and the secondary air can be the same, and is in common use with lower amperage PAC systems that use filtered, compressed shop air for both cutting and shielding.

_____ f. Oxygen should not be used as cutting air with a system that has used compressed air unless the compressed air system has been carefully cleaned.

Objective 13

Solve problems concerning PAC consumables, their characteristics and maintenance by circling the number of the item that best solves each of the following problems.

a. You suspect that a cutting problem may be caused by shielding cup wear. To check for cup wear, you should:

(1) Look for spatter and dross that may have formed on the cup.
(2) Look for wear along the face of the cup.
(3) Look for worn, cracked or burned spots that would interfere with performance.

b. You have experienced an erratic arc on a PAC job, and you suspect the trouble is with the cutting nozzle. You should:

(1) Unscrew the nozzle to see if it is stopped up.
(2) Unscrew the nozzle and look for an elongated orifice or an orifice that is obviously oversized.
(3) Take no chances. Simply replace the nozzle.

c. You have placed a new nozzle on a torch. To properly complete the job, you should:

  (1) Tighten the nozzle until it is snug, never overtighten.
  (2) Tighten the nozzle until it is very tight.

Objective 14

Solve problems concerning PAC system duty cycles by circling the number of the item that best solves each of the following problems.

a. You're starting a PAC job that will require a setting of 70 amps. A plate attached to the machine indicates that the duty cycle at 70 amps is 60 percent. This means:

  (1) Do not run the machine more than 60 percent of an eight-hour workday.
  (2) Do not run the machine more than six minutes out of each ten-minute period.
  (3) Run the machine for six minutes straight and then let it cool for six minutes.

b. You're working a PAC system that suddenly overheats and automatically shuts off. You should:

  (1) Immediately turn off the supply power and let the machine cool down.
  (2) Stop the cutting activity, but leave the machine running so the internal fan can help cool machine components.
  (3) Report the machine to a supervisor and find another machine to finish the job.

Objective 15

Select true statements concerning guidelines for setting PAC flow rate and flow pressure by placing an "X" in the blanks next to the true statements.

_____ a. Flow rate for PAC systems is expressed in Scfh and flow pressure is expressed in p.s.i. or p.s.i.g.

_____ b. Flow rate in Scfh is different from flow rate in cfh in that Scfh references a standard.

_____ c. The important thing to remember about flow pressure is to keep the p.s.i. at exactly 70 p.s.i.

_____ d. Flow pressure in a PAC system may sometimes vary as much as ten pounds plus or minus without affecting equipment, but pressure too high will quickly deteriorate an electrode, and pressure too low will quickly deteriorate a cutting nozzle.

_____ e. All PAC systems have safety interlocks that shut the PAC machine off if flow pressure drops below a minimum point, usually around 20 p.s.i.

Objective 16

Solve problems concerning guidelines for using compressed air with a PAC system by circling the number of the item that best solves each of the following problems.

a. You've been asked to check out a compressed air supply for use with a dual-flow PAC system. You need to:

(1) Make sure the air supply can reach the PAC system.
(2) Make sure the air supply is clean, dry, and oil-free.
(3) Make sure the air supply has high pressure capability.

b. You've been instructed to set up a PAC system for cutting. For proper set up, you should:

(1) Make sure the air supply is turned on.
(2) Drain or air purge the sediment bowl on the air regulator and use the adjusting device to set p.s.i.
(3) Run plenty of air through the torch to make sure the air is clean and dry.

Objective 17

Select true statements concerning factors affecting cutting speeds by placing an "X" in the blanks next to the true statements.

Note: For a statement to be true, all parts of the statements must be true.

_____ a. Several factors affect cutting speeds for PAC, but the most important factors are:

- Power input
- Characteristics of gas flow, both cutting and secondary
- Nozzle design and orifice diameter
- Metal thickness

_____ b. Other factors affecting cutting speeds are the condition of the equipment, the degree of wear on consumable parts, and operator skills.

_____ c. Cutting speeds for mechanized PAC are considerably slower than speeds for hand cutting, but that is because mechanized systems are used for cutting thicker metals.

Objective 18

Select true statements concerning techniques for contact and stand-off cutting by placing an "X" in the blanks next to the true statements.

_____ a. For normal contact cutting, hold the torch with the arc directed at a slight angle opposite the direction of travel.

_____ b. For stand-off cutting, change to the appropriate shield cup or stand-off device, and direct the arc at a 90° angle straight down at the workpiece.

Written Test

Objective 19

Select true statements concerning techniques for cutting expanded metal by placing an "X" in the blanks next to the true statements.

_____ a. With some PAC systems, cutting expanded metal can be a problem because the arc has to be frequently restarted because of the thickness of the metal.

_____ b. To eliminate the problem with restarting the arc, place a thin piece of metal on top of the expanded metal, a straightedge is ideal.

_____ c. Be sure the metal or straightedge is clamped in place so it will not have to be handled during the cutting process.

_____ d. Drag the cutting nozzle along the metal guide, and there should be no problem with having to restart the arc.

Objective 20

Solve problems concerning techniques for gouging metal by circling the number of the item that best solves each of the following problems.

a. When you're setting up for gouging metal, you should:

(1) Raise the amperage and increase p.s.i.
(2) Change to a different electrode.
(3) Change to the recommended electrode and install a gouging nozzle on the torch.

b. As you're gouging a piece of mild steel, you notice the need for a deeper gouge. You should:

(1) Increase the torch angle.
(2) Slow your travel speed.
(3) Decrease the torch angle.

c. You're working at the job of removing an inferior weld and notice that you need a wider gouge. You should:

(1) Stop gouging long enough to change to a different gouging nozzle.
(2) Weave with the torch to give you a wider gouge.
(3) Slow your cutting speed and increase amperage.

Objective 21

Select true statements concerning techniques for piercing and beveling metal by placing an "X" in the blanks next to the true statements.

_____ a. Spray the shield cup with or dip the cup in antispatter compound to help minimize spatter and scale that adheres to the cup.

_____ b. Start at a point slightly removed from the cut line and angle the torch slightly to blow particles away from the torch rather than back into the torch.

_____ c. Move from the point that was pierced to the cutting line and finish the cut, and then clean any spatter or scale from the shield cup.

_____ d. To bevel with a PAC system, angle the torch to the desired bevel angle, maintain a 90° angle over the workpiece, and make the cut.

Objective 22

Match cutting problems with their probable causes by inserting the name of the problem in the appropriate blanks in the following chart.

Problem	Probable Cause
a. ____________________	Improper cutting speed Worn or damaged torch parts
b. ____________________	Cutting speed too slow Stand-off too high
c. ____________________	Cutting speed too fast Torch tilted too much Metal too thick Worn or damaged torch parts

*Permission to duplicate this test is granted.

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Answers to Written Test

Objective 1	a. 5 b. 6 c. 3 d. 4 e. 11 f. 9 g. 1 h. 10 i. 8 j. 2 k. 7
Objective 2	a. High temperature b. "Ionized" c. Constricted d. No preheating e. High-velocity
Objective 3	a. 5 b. 4 c. 1 d. 3 e. 2
Objective 4	a, b, c, d
Objective 5	a. Decreases b. High noise levels c. Nine d. Burn e. Ventilated f. Hazardous materials
Objective 6	a. 2 b. 1 c. 1
Objective 7	a, b, c, d, e
Objective 8	a, b, d, e, f
Objective 9	a. 3 b. 2
Objective 10	a, c, d
Objective 11	a. 2 b. 3

Answers to Written Test

Objective 12	a, b, c, e, f
Objective 13	a. 3 b. 2 c. 1
Objective 14	a. 2 b. 2
Objective 15	a, b, d
Objective 16	a. 2 b. 2
Objective 17	a, b
Objective 18	b
Objective 19	b, c, d
Objective 20	a. 3 b. 1 c. 2
Objective 21	a, b, c
Objective 22	a. Dross formation b. Main arc extinguishes c. Insufficient penetration

Teacher Supplement 1—Water Cutting With PAC Systems

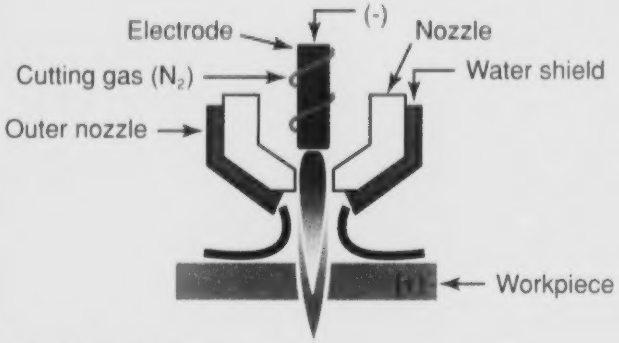
Introduction

Many mechanized PAC systems use water cutting of one form or another. The early use of water to replace the secondary PAC gas led to improvements in cut quality, but as PAC water systems improved, the results were not only better cut quality, but effective containment of the smoke, fumes, and dangerous ultraviolet rays that are byproducts of the PAC process. The following items briefly present some basics of PAC water cutting that should help students appreciate the rapid improvements in PAC and its permanent place in the skills requirements for welders and cutters.

Water Shield Systems

Water shield systems basically replaced the secondary shielding gas with water. The water shield improved cut squareness, but did not provide additional arc restriction required for improved cutting speed and general cut quality.

Figure 1



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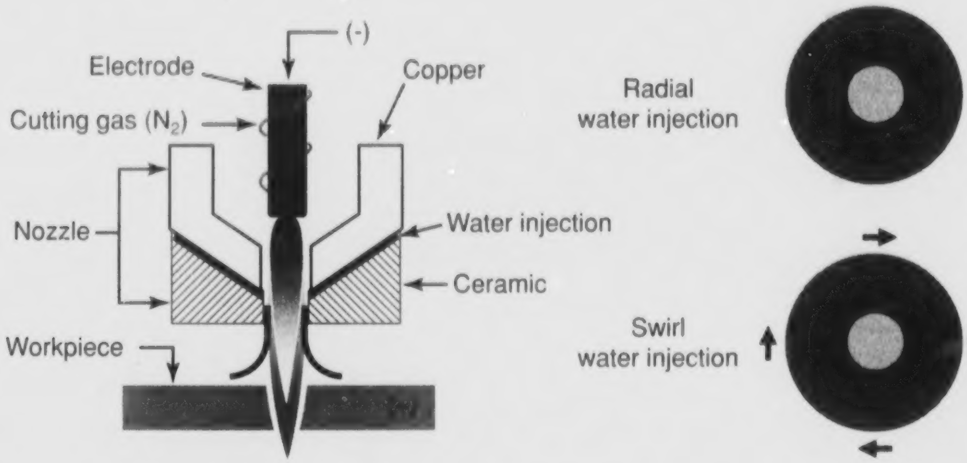
Teacher Supplement 1

Water Injection Systems

Water injection systems employ either a radial water injection pattern or a swirl water injection pattern. In either case the injection systems not only improved cut squareness, they increased cutting speeds and eliminated dross when cutting mild steel.

Figure 2


(-)
Electrode
Copper
Cutting gas (N_2)
Nozzle
Water injection
Ceramic
Workpiece
Radial
water injection
Swirl
water injection

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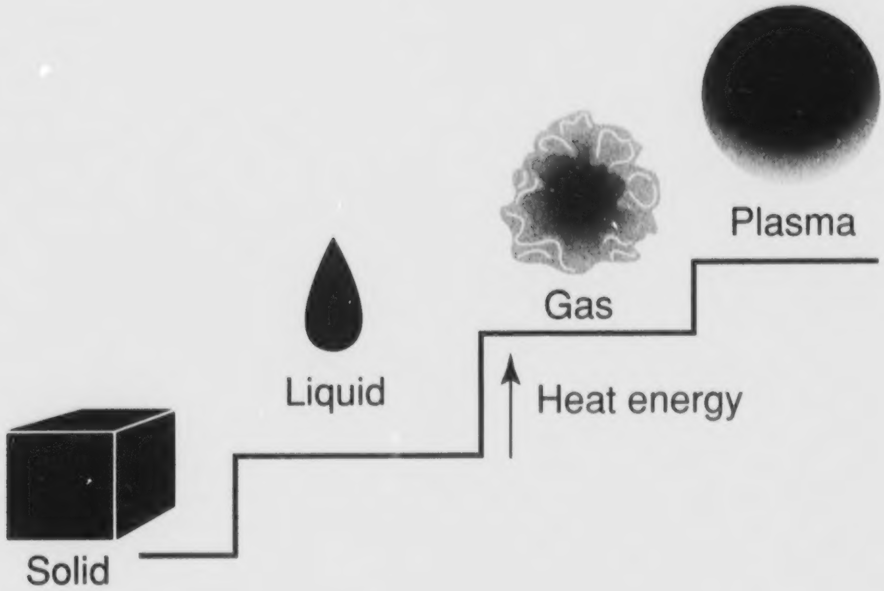
Underwater Cutting Systems

In a water table PAC system, the cutting table is filled with water up to the level of the underside of the workpiece, and the cutting nozzle is surrounded with a water shroud.

In an underwater PAC system, the cutting nozzle and the workpiece are submerged in two to three inches of water; when the torch is not cutting underwater, a constant flow of compressed air keeps water out of the torch. Underwater systems have helped eliminate the fumes, smoke, and noise that are part of the PAC process. With special dyes placed in the water, even the ultraviolet rays have been eliminated to improve operator safety.

Permission to duplicate this supplement is granted.

Plasma Arc Cutting


Plasma
Gas
Liquid
Heat energy
Solid

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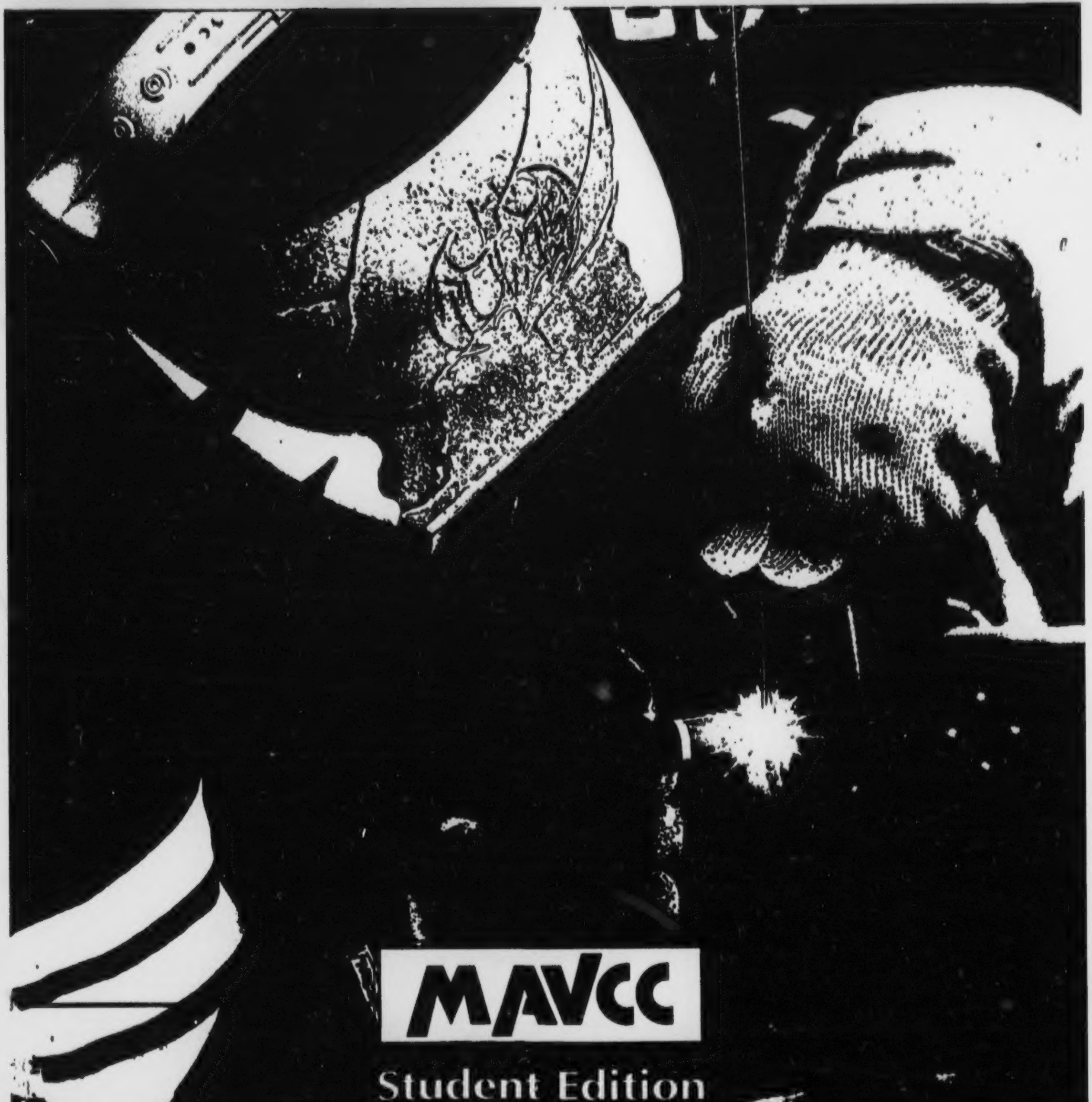
Gas Tungsten Arc Welding and Plasma Arc Cutting

SECOND EDITION



MAVCC

Student Edition

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Gas Tungsten Arc Welding and Plasma Arc Cutting

Second Edition

Student Edition

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Unit 1 GTAW Orientation and Safety

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*Assignment Sheet

1—Solve Problems Concerning GTAW Safety 1

*The Assignment Sheet is located in the Student Workbook.

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Prerequisites:
None

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 through 6.

Optional

☐ 4. **View** Videotape entitled *Arc Welding Safety* and/or *Health and Safety Factors in Welding Operation.*

☐ 5. **Study** Information Sheet, Objectives 7 through 15.

☐ 6. **Do** Assignment Sheet 1, "Solve Problems Concerning GTAW Safety."

☐ 7. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 8. If the evaluation is not satisfactory, repeat steps 3, 5, and 6.

☐ 8. **Check** With instructor for any additional assignments to be completed.

☐ 9. **Do** Additional assignments listed below.

☐ 10. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 11. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

Objective Sheet

Unit Objective

After completing this unit, the student should be able to discuss safety requirements for gas tungsten arc welding and solve problems concerning GTAW safety. The student should demonstrate these competencies by completing the assignment sheet and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to GTAW orientation and safety with their definitions.
2. Select true statements concerning advantages of GTAW.
3. Select true statements concerning limitations of GTAW.
4. Complete statements concerning principles of GTAW.
5. Complete statements concerning GTAW applications.
6. Complete statements concerning benefits from learning GTAW.
7. Select true statements concerning electrical safety guidelines for GTAW.
8. Solve problems concerning guidelines for duty cycle safety.
9. Select true statements concerning important rules for handling welding cables and gas and coolant hoses.
10. Select true statements concerning rules for handling hollow castings and containers.
11. Complete statements concerning hazards associated with arc rays.
12. Complete statements concerning types of welding hoods and their characteristics.
13. Solve problems concerning guidelines for selecting a safe lens shade for GTAW.
14. Select true statements concerning protective clothing requirements for GTAW.
15. Complete statements concerning environmental safety requirements.

*16. Solve problems concerning GTAW safety. (Assignment Sheet 1)

*The Assignment Sheet is located in the Student Workbook.

Information Sheet

Objective 1

Terms and definitions

a. **Backup purge**—A gas supplied to the back side of a weldment to prevent atmospheric contamination during the root pass

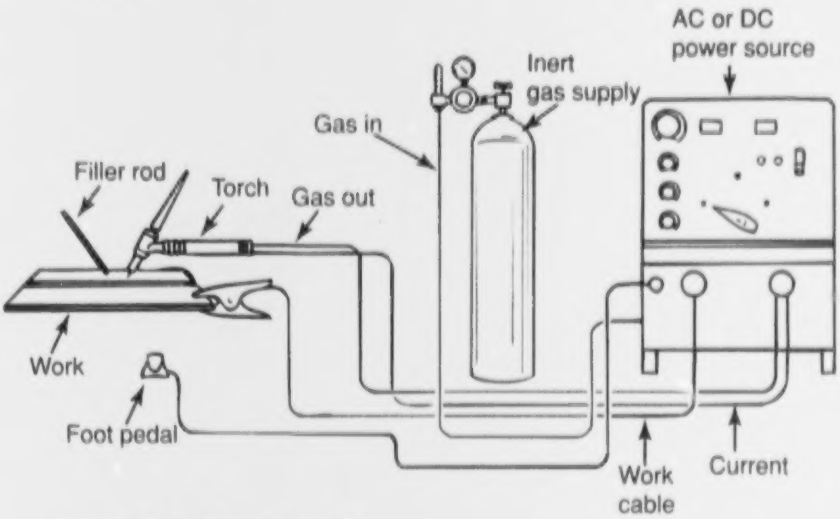
b. **Contaminants**—Elements in the atmosphere and/or impurities formed from chemical reactions between a base metal, filler metal, electrode, or shielding gas

c. **Deposition rate**—The weight of filler metal placed onto a weld in a given period of time

d. **Gas tungsten arc welding (GTAW)**—An arc welding process that produces coalescence of metals by heating them with an arc between a nonconsumable tungsten electrode and a workpiece; shielding is obtained from a gas

Note: Pressure may or may not be used, and filler metal may or may not be used. GTAW is often referred to as TIG (Tungsten Inert Gas).

Figure 1



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e. **Heliarc**—A trade name sometimes used to identify the gas tungsten arc welding process when helium is used as the primary gas; it is very expensive

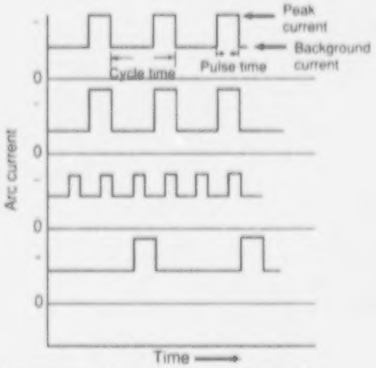
f. **Inert gas**—A gas that normally does not combine chemically with a base metal or filler metal

g. **Nonconsumable**—Material that does not melt or transfer to a weld

h. **Oxygen displacement**—The tendency of any arc or flame to reduce oxygen in the breathing zone around a welding activity

i. **Pulsed gas tungsten arc welding (GTAW-P)**—A gas tungsten arc welding process variation in which the current is pulsed from a low (background) value to a high (peak) value

Figure 2



Courtesy of Lincoln Electric Company.

j. **Shielding gas**—Protective gas used to prevent atmospheric contamination during a welding procedure

k. **Toxic hazards**—Poisonous gases, fumes, and vapors produced by chemical reactions in certain welding processes

Objective 2

Advantages of GTAW

a. High quality welds can be made in all weldable metals and alloys except the very low melting alloys.

b. GTAW uses no flux, produces no slag or spatter, and requires no after-weld cleaning.

c. GTAW is excellent for the root pass on carbon and stainless steel pipe.

d. The controlled heat concentration with GTAW reduces distortion and stress in base metals.

e. The GTAW process is good for welding thin or small items in a variety of metals.

f. With GTAW, the operator can clearly see the arc and weld puddle, and the operator has close control of current and the welding process.

g. Filler metal can be added to the weld pool independently.

Objective 3

Limitations of GTAW

a. GTAW will not function in a windy environment.

b. Deposition rate with GTAW is low, compared to other processes.

c. Equipment is more costly for start up than for GMAW or SMAW.

d. The slower welding speeds with GTAW increase production costs.

e. GTAW requires greater skill to master the process.

Objective 4

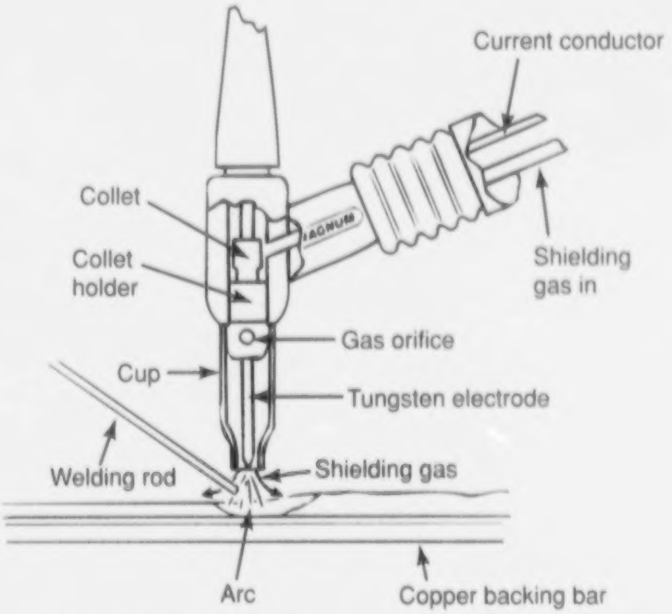
Principles of GTAW

a. The heat needed for fusion is generated by an arc between a nonconsumable tungsten electrode and a base metal.

b. As heat is generated from the arc, a shielding gas surrounds the arc stream and the molten puddle formed by the arc and helps to stabilize the arc and protect the puddle from contaminants.

c. Filler metal may be added with a filler rod inserted into the weld puddle where it is also protected by the shielding gas.

Figure 3


Current conductor
Collet
Collet holder
AGNUM
Shielding gas in
Gas orifice
Cup
Tungsten electrode
Welding rod
Shielding gas
Arc
Copper backing bar

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Information Sheet

Objective 5

GTAW applications

a. With GTAW, welding is possible in all positions.

b. GTAW can be done on a wide range of metals and thicknesses.

c. GTAW is especially effective where precise heat control is necessary for a quality weld such as in aircraft assembly or small, irregular shaped objects.

d. GTAW is good to excellent for all aluminum applications, and especially good on other thin ferrous and nonferrous metals.

Objective 6

Benefits from learning GTAW

a. GTAW introduces a beginning welder to the concept of a nonconsumable electrode and shielding gases and their uses.

b. GTAW challenges the student to improve manipulative skills and eye-hand coordination.

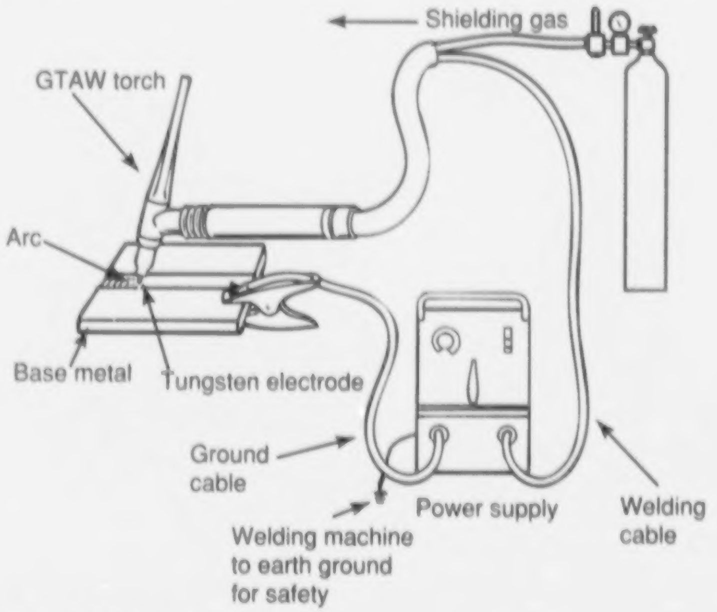
c. Beginning welders may go to work in a place where there is no opportunity to learn GTAW, so learning GTAW early provides a beginner with an opportunity to achieve skills that will bring better jobs and high pay.

Objective 7

Electrical safety guidelines for GTAW

a. All electrical equipment should have an earth ground for safety reasons, and this ground should not be confused with the work lead to workpiece ground that completes the welding circuit.

Figure 4


Shielding gas
GTAW torch
Arc
Base metal
Tungsten electrode
Ground cable
Welding machine to earth ground for safety
Power supply
Welding cable

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b. Keep electrical connections tight, clean, and dry because poor connections can heat up, cause bad welds, produce dangerous arcs and sparking, and even melt.

c. Keep work area, equipment, and clothing dry because even a slight amount of moisture can conduct enough electricity to cause a severe shock.

d. Never dip a torch in water to cool it.

e. Disconnect and lock out all electric power sources before doing any work on electrical equipment.

f. Keep welding cable as close to the work area as possible and do not connect cables to building framework because current can be directed through lifting chains and cables and weaken them.

g. When working in high places, carefully examine work area for electrical hazards because a shock in such conditions could cause a fall and severe injury.

h. When using a high frequency intensity control for GTAW, set the control at a minimum setting for the job activity to avoid interfering with nearby communications equipment.

i. Make sure that all GTAW machines using high frequency controls have both input and output grounded to avoid erratic frequency interference.

Note: In production facilities where applications are numerically controlled with punch-type magnetic tape, improper grounding can cause erratic interference that will alter or erase the tapes.

Objective 8

Guidelines for duty cycle safety

a. Duty cycle is a performance reference used to avoid overheating and perhaps ruining a welding machine.

b. Duty cycle is based on a ten minute period and the length of time during that period that a machine can be safely operated.

c. A machine with a 20 percent duty cycle could safely operate 2 minutes out of each 10 minute period.

d. Since duty cycle is rated at the maximum output of a welding machine at a given amperage setting, the lower the percentage, the more attention is required to time spent actually welding.

Objective 9

Important rules for handling welding cables and gas and coolant hoses

a. Never drag cables or hoses through dirt or oil, and never pull a cable to force it over an obstruction.

b. Use only clean dry rags to clean cables and hoses.

> **Caution:** Never use gasoline or an oily rag on cables and hoses.

c. When not in use, keep cables and hoses coiled free of kinks and properly stored.

d. Never drape a welding cable over any type of gas cylinder, and NEVER strike an arc on a gas cylinder.

e. Never interchange gas and water hoses.

f. Disconnect and remove electrode holders and cables used for SMAW.

g. Keep cables off metal tables or any grounding surfaces.

h. Make sure water-cooled systems have water turned off when shutting down.

i. Use welding cable covers.

Objective 10

Rules for handling hollow castings and containers

a. Vent hollow castings or containers before heating, cutting, or welding on them.

b. Do not heat, cut, or weld on tanks, drums, and sealed containers.

Objective 11

Hazards associated with arc rays

a. A GTAW arc produces ultraviolet and infrared radiation that can severely burn eyes that are unprotected with a proper shade of protective lens.

Note: A welding hood or helmet protects the head from flying sparks, but the shaded lens is also required for eye protection.

b. Radiation from a GTAW arc is strong enough to sunburn or sometimes blister bare skin if the exposure is intense or for an extended period, so arms, legs, and torso should be covered with durable flame-resistant clothing.

c. Workstations and work areas should be shielded to prevent an arc flash from injuring nearby workers or visitors.

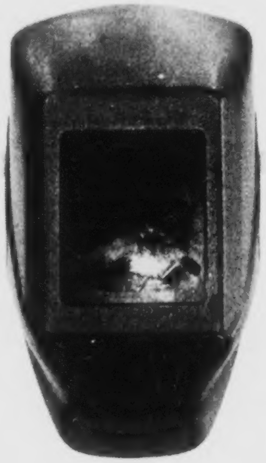
Objective 12

Types of welding hoods and their characteristics

a. **Stationary filter lens**—This type hood has a fixed lens housing with the shaded lens held in by a spring retainer from where a lens can be slipped out and replaced as welding requires.

Note: Always check the clear face lens to make sure it's clean and free of scratches.

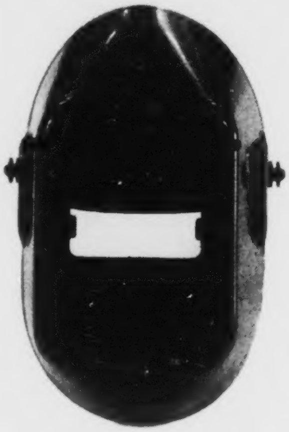
Figure 5



b. **Flip-front filter lens**—This type hood has a lens housing with a front side that can be flipped up so that it leaves a clear-glass or plastic lens that permits the hood to be worn while chipping.

Note: Always check the clear face lens to make sure it's clean and free of scratches.

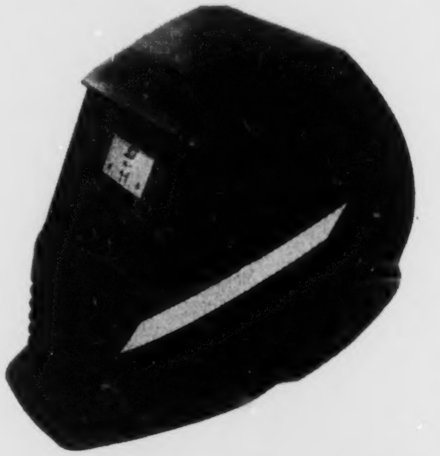
Figure 6



c. **Auto darkening lens**—This type of lens is used with a helmet specifically designed for auto darkening lenses.

- Contains sensors that automatically change the shade lens from clear to dark in a fraction of a second when you start to weld
- Gradually changes from dark to clear when you stop welding
- Can be manually adjusted to a variety of shades

Figure 7



Objective 13

Guidelines for selecting a safe lens shade for GTAW

a. Determine electrode size and amperage range for the electrode.

Note: In oxyacetylene welding and cutting, lens shade requirements are based on metal thickness, but in gas-shielded arc welding, lens shade requirements are based on electrode size, amperage range of the electrode, and base metal properties.

b. Select lens shade according to the lens manufacturer's selection chart, but never select less than a #8 lens shade for GTAW.

c. When you remove your hood after welding and you see white spots or white blotches as after images, it means that you are getting too much light through the lens and you should switch to a shade at least one number darker, or check the seal on your lens.

Recommended Lens Shades for Various Welding Current Ranges

Shade No.	Welding Current, A
8	Up to 75
10	75 to 200
12	200 to 400
14	Above 400

Adapted from American Welding Society, 1991, *Welding Handbook* Vol. 2, *Welding Processes*, Table 3.7.

Objective 14

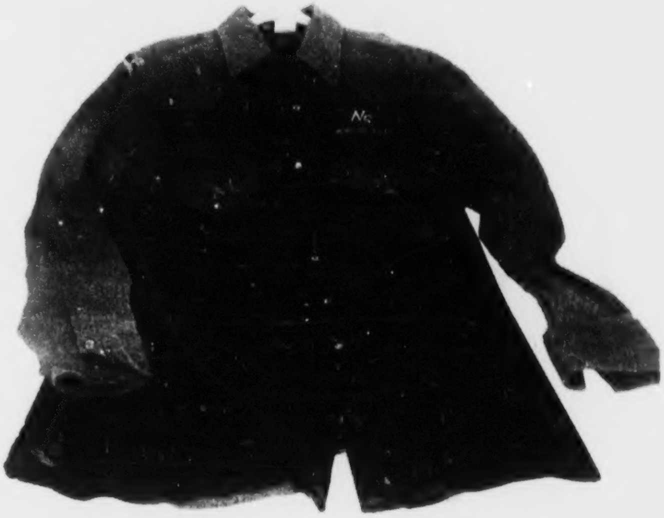
Protective clothing required for GTAW

Caution: Always avoid clothing with tears, snags, rips, or worn spots. They are easily ignited by sparks.

a. Shirts

- Should be heavy, long-sleeve shirts with pocket flaps
- Keep collar and sleeves buttoned to keep out sparks, and remove pockets from front of shirt or tape them shut if they don't have pocket flaps

Figure 8



b. Pants

- Should not have cuffs
- Should be long enough to come down over shoe/boot tops

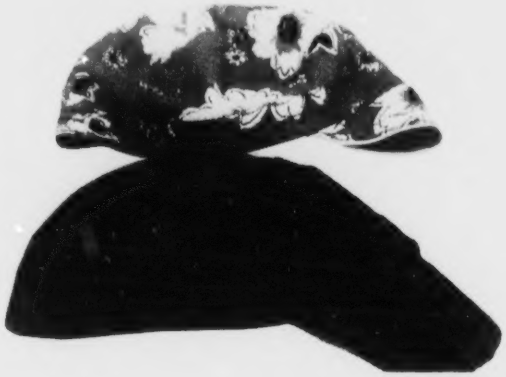
Caution: Clothes made of polyester and other synthetics catch fire easily so it's better to wear wool or heavily-starched cottons.

c. Welding caps

- Should be worn to protect hair from sparks and spatter
- Should have a flexible bill that can be slipped around to cover either ear to keep sparks or metal spatter out of the ear opening

Caution: Some hair sprays are highly flammable and can be ignited by sparks, and any kind of plastic hair cap or covering is dangerous in the welding area.

Figure 9



d. Boots

- Should be made of heavy leather with uppers that reach above the ankle to help prevent burns from sparks and spatter
- Should be steel toed

  Note: Steel-toed boots are required in many states.

- If low-topped shoes are worn, the ankles should be protected by fire-resistant leggings.

  Note: Never wear sneakers, tennis shoes, sandals, or loafer-type shoes when welding.

e. Gloves—Wear lightweight leather gloves designed especially for GTAW.

f. Jackets and aprons—Leather jackets and aprons should be worn for additional protection, especially when welding out of position or in confined areas where flying sparks present an increased hazard.

Figure 10

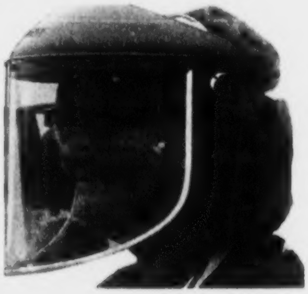
g. Safety glasses

- Should have nonmetal frames
- Should have impact-resistant lenses with side shields to protect from flying objects
- Should be worn at all times in the shop area

Figure 11

h. Face shield—Wear a clear-plastic type of face shield to provide good visibility when grinding or sanding base metals for GTAW.

Figure 12



Objective 15

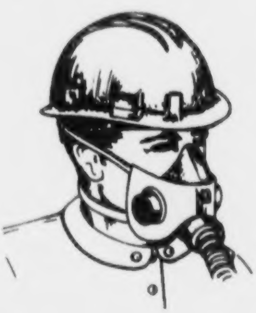
Environmental safety requirements

a. **Ventilation**—Many welding activities produce toxic fumes and vapors that are hazardous to breathe, and every workstation should be equipped with a ventilation or exhaust system capable of safely removing dangerous and irritating smoke and contaminants.

> **Caution:** Over ventilation can interfere with the welding process, so make proper considerations and always position your head out of the path of rising fumes.

b. **Respirators**—In confined areas where the hazard of toxic fumes is increased, a welder should wear an air-supplied respirator or a self-contained breathing apparatus, not a filter-type mask that cannot compensate for oxygen displacement.

Figure 13



> **Caution:** Argon is much heavier than air and will quickly displace oxygen, so be especially careful using the GTAW process in confined areas, even though they appear to have adequate ventilation.

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c. **Noise**—This is a workplace hazard frequently overlooked, but earplugs or muffler-type ear protectors should be worn when the work area subjects a welder to high noise levels, especially high noise levels that are continuous.

d. **Lighting**—Lighting in a work area or at a workstation should be bright enough to provide good visibility free of glare because poorly lit work areas contribute to eye fatigue, irritation, and poor work.

Unit 2 GTAW Equipment, Applications, and Techniques

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*The Job Sheets are located in the Student Workbook.

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Prerequisites:
Unit 1

Learning Activities Sheet

Student Name ____________________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 through 10.

Optional

☐ 4. **View** Videotape entitled *Gas Tungsten Arc Welding.*

☐ 5. **Study** Information Sheet, Objectives 11, 12, and 13.

☐ 6. **Observe** Demonstration of procedures to be used in completing Job Sheet 1.

☐ 7. **Do** Job Sheet 1, "Set Up a Flow Meter Regulator for GTAW Shielding Gases."

☐ 8. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 9. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat steps 5, 6, and 7.

☐ 9. **Study** Information Sheet, Objectives 14 through 18.

☐ 10. **Observe** Demonstration of procedures to be used in completing Job Sheet 2.

☐ 11. **Do** Job Sheet 2, "Set Up and Shut Down GTAW Equipment for Welding Mild or Stainless Steel."

☐ 12. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 13. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat steps 9, 10, and 11.

☐ 13. **Study** Information Sheet, Objective 19 and Student Supplement 1.

Learning Activities Sheet

☐ 14. **Observe** Demonstration(s) of procedures to be used in completing Job Sheet 3 and Job Sheet 4.

☐ 15. **Do** **Job Sheet 3**, "Prepare Mild or Stainless Steel for GTAW" and **Job Sheet 4**, "Prepare a Tungsten Electrode for Welding Mild or Stainless Steel."

☐ 16. **Stop** After completing each job sheet, have your instructor evaluate your performance. If the evaluation is satisfactory, continue to the next job sheet. If the evaluation is not satisfactory, study the procedure outlined in that job sheet, and redo the job sheet. After satisfactorily completing Job Sheet 3 and Job Sheet 4, continue to step 17.

☐ 17. **Study** Information Sheet, Objectives 20, 21, and 22 and Student Supplement 2.

☐ 18. **Observe** Demonstration(s) of procedures to be used in completing Job Sheet 5 and Job Sheet 6.

☐ 19. **Do** **Job Sheet 5**, "Strike and Maintain an Arc to Make Stringer Beads on Mild or Stainless Steel Without Filler Metal in the Flat Position" and **Job Sheet 6**, "Strike and Maintain an Arc to Make Stringer Beads on Mild or Stainless Steel With Filler Metal in the Flat Position."

☐ 20. **Stop** After completing each job sheet, have your instructor evaluate your performance. If the evaluation is satisfactory, continue to the next job sheet. If the evaluation is not satisfactory, study the procedure outlined in that job sheet, and redo the job sheet. After satisfactorily completing Job Sheet 5 and Job Sheet 6, continue to step 21.

☐ 21. **Study** Information Sheet, Objective 23 and Objective 24 and Student Supplement 3.

☐ 22. **Observe** Demonstration(s) of procedures to be used in completing Job Sheet 7 and Job Sheet 8.

☐ 23. **Do** **Job Sheet 7**, "Weld to Specifications a Fillet Weld Lap Joint on Mild or Stainless Steel in the Flat Position" and **Job Sheet 8**, "Weld to Specifications a Fillet Weld T-Joint on Mild or Stainless Steel in the Flat Position."

☐ 24. **Stop** After completing each job sheet, have your instructor evaluate your performance. If the evaluation is satisfactory, continue to the next job sheet. If the evaluation is not satisfactory, study the procedure outlined in that job sheet, and redo the job sheet. After satisfactorily completing Job Sheet 7 and Job Sheet 8, continue to step 25.

☐ 25. **Observe** Demonstration of procedures to be used in completing Job Sheet 9.

☐ 26. **Do** Job Sheet 9, "Weld to Specifications an Open-Root Square-Groove Butt Joint on Mild or Stainless Steel in the Flat Position."

☐ 27. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 28. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 9 and repeat steps 25 and 26.

☐ 28. **Observe** Demonstration(s) of procedures to be used in completing Job Sheets 10 through 16.

☐ 29. **Do** **Job Sheet 10**, "Weld to Specifications a Fillet Weld Lap Joint on Mild or Stainless Steel in the Horizontal Position," **Job Sheet 11**, "Weld to Specifications a Fillet Weld T-Joint on Mild or Stainless Steel in the Horizontal Position," **Job Sheet 12**, "Weld to Specifications a Fillet Weld Lap Joint on Mild or Stainless Steel in the Vertical Position," **Job Sheet 13**, "Weld to Specifications a Fillet Weld T-Joint on Mild or Stainless Steel in the Vertical Position," **Job Sheet 14**, "Weld to Specifications an Open-Root Square-Groove Butt Joint on Mild or Stainless Steel in the Vertical Position," **Job Sheet 15**, "Weld to Specifications a Fillet Weld Lap Joint on Mild or Stainless Steel in the Overhead Position," **Job Sheet 16**, "Weld to Specifications a Fillet Weld T-Joint on Mild or Stainless Steel in the Overhead Position."

☐ 30. **Stop** After completing each job sheet, have your instructor evaluate your performance. If the evaluation is satisfactory, continue to the next job sheet. If the evaluation is not satisfactory, study the procedure outlined in that job sheet, and redo the job sheet. After satisfactorily completing Job Sheets 10 through 16, continue to step 31.

☐ 31. **Observe** Demonstration(s) of procedures to be used in completing Job Sheets 17, 18, and 19.

Learning Activities Sheet

☐ 32. **Do** **Job Sheet 17**, "Set Up and Shut Down GTAW Equipment for Welding Aluminum," **Job Sheet 18**, "Prepare Aluminum for GTAW," **Job Sheet 19**, "Prepare a Tungsten Electrode for Welding Aluminum."

☐ 33. **Stop** After completing each job sheet, have your instructor evaluate your performance. If the evaluation is satisfactory, continue to the next job sheet. If the evaluation is not satisfactory, study the procedure outlined in that job sheet, and redo the job sheet. After satisfactorily completing Job Sheets 17, 18, and 19, continue to step 34.

☐ 34. **Observe** Demonstration(s) of procedures to be used in completing Job Sheet 20 and Job Sheet 21.

☐ 35. **Do** **Job Sheet 20**, "Strike and Maintain an Arc to Make Stringer Beads on Aluminum Without Filler Metal in the Flat Position" and **Job Sheet 21**, "Strike and Maintain an Arc to Make Stringer Beads on Aluminum With Filler Metal in the Flat Position."

☐ 36. **Stop** After completing each job sheet, have your instructor evaluate your performance. If the evaluation is satisfactory, continue to the next job sheet. If the evaluation is not satisfactory, study the procedure outlined in that job sheet, and redo the job sheet. After satisfactorily completing Job Sheet 20 and Job Sheet 21, continue to step 37.

☐ 37. **Observe** Demonstration(s) of procedures to be used in completing Job Sheets 22 through 31.

☐ 38. **Do** **Job Sheet 22**, "Weld to Specifications a Fillet Weld Lap Joint on Aluminum in the Flat Position," **Job Sheet 23**, "Weld to Specifications a Fillet Weld T-Joint on Aluminum in the Flat Position," **Job Sheet 24**, "Weld to Specifications a Square-Groove Butt Joint on Aluminum in the Flat Position," **Job Sheet 25**, "Weld to Specifications a Fillet Weld Lap Joint on Aluminum in the Horizontal Position," **Job Sheet 26**, "Weld to Specifications a Fillet Weld T-Joint on Aluminum in the Horizontal Position," **Job Sheet 27**, "Weld to Specifications a Fillet Weld Lap Joint on Aluminum in the Vertical Position," **Job Sheet 28**, "Weld to Specifications a Fillet Weld T-Joint on Aluminum in the Vertical Position," **Job Sheet 29**, "Weld to Specifications a Square-Groove Butt Joint on Aluminum in the Vertical Position," **Job Sheet 30**, "Weld to Specifications a Fillet Weld Lap Joint on Aluminum in the Overhead Position," and **Job Sheet 31**, "Weld to Specifications a Fillet Weld T-Joint on Aluminum in the Overhead Position."

☐ 39. **Stop** After completing each job sheet, have your instructor evaluate your performance. If the evaluation is satisfactory, continue to the next job sheet. If the evaluation is not satisfactory, study the procedure outlined in that job sheet, and redo the job sheet. After satisfactorily completing Job Sheets 22 through 31, continue to step 40.

☐ 40. **Check** With instructor for any additional assignments to be completed.

☐ 41. **Do** Additional assignments listed below.

____

____

____

☐ 42. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 43. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

Unit 2 GTAW Equipment, Applications, and Techniques

Objective Sheet

Unit Objective

After completing this unit, the student should be able to troubleshoot GTAW machine and process problems, and weld to specifications lap joints, T-joints, and butt joints in all positions on mild and stainless steel and aluminum. The student should demonstrate these competencies by completing the job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to GTAW equipment, applications, and techniques with their definitions.
2. Match GTAW machine controls with their functions.
3. Complete statements concerning the concept of pulse current and its use in GTAW.
4. Differentiate between types of GTAW systems.
5. Select true statements concerning cooling system safety.
6. Complete definitions of types of power cables and their characteristics.
7. Identify basic parts of a GTAW torch.
8. Complete statements concerning the gas lens and its uses.
9. Match types of nozzles with their functions.
10. Arrange in order the steps in GTAW nozzle selection.
11. Select true statements concerning GTAW shielding gases and their characteristics.
12. Select true statements concerning flow meter design and use.
13. Complete statements concerning flow rates for GTAW shielding gases.
14. Complete a chart concerning tungsten electrodes, their characteristics and applications.
15. Select true statements concerning guidelines for preparing tungsten electrodes for DC welding.
16. Complete statements concerning guidelines for grinding electrodes for DC welding.
17. Solve problems concerning guidelines for preparing electrodes for AC welding.

Objective Sheet

18. Select true statements concerning guidelines for GTAW electrode extension.

19. Select true statements concerning guidelines for filler metal selection and use.

20. Complete statements concerning requirements for base metal preparation.

21. Select true statements concerning special problems with contamination and air movement.

22. Arrange in order the steps for manual welding with a filler rod.

23. Select true statements concerning backup bars and their use in GTAW.

24. Complete statements concerning guidelines for troubleshooting GTAW problems.

*25. Set up a flow meter regulator for GTAW shielding gases. (Job Sheet 1)

*26. Set up and shut down GTAW equipment for welding mild or stainless steel. (Job Sheet 2)

*27. Prepare mild or stainless steel for GTAW. (Job Sheet 3)

*28. Prepare a tungsten electrode for welding mild or stainless steel. (Job Sheet 4)

*29. Strike and maintain an arc to make stringer beads on mild or stainless steel without filler metal in the flat position. (Job Sheet 5)

*30. Strike and maintain an arc to make stringer beads on mild or stainless steel with filler metal in the flat position. (Job Sheet 6)

*31. Weld to specifications a fillet weld lap joint on mild or stainless steel in the flat position. (Job Sheet 7)

*32. Weld to specifications a fillet weld T-joint on mild or stainless steel in the flat position. (Job Sheet 8)

*33. Weld to specifications an open-root square-groove butt joint on mild or stainless steel in the flat position. (Job Sheet 9)

*34. Weld to specifications a fillet weld lap joint on mild or stainless steel in the horizontal position. (Job Sheet 10)

*35. Weld to specifications a fillet weld T-joint on mild or stainless steel in the horizontal position. (Job Sheet 11)

*36. Weld to specifications a fillet weld lap joint on mild or stainless steel in the vertical position. (Job Sheet 12)

*37. Weld to specifications a fillet weld T-joint on mild or stainless steel in the vertical position. (Job Sheet 13)

*38. Weld to specifications an open-root square-groove butt joint on mild or stainless steel in the vertical position. (Job Sheet 14)

*39. Weld to specifications a fillet weld lap joint on mild or stainless steel in the overhead position. (Job Sheet 15)

*40. Weld to specifications a fillet weld T-joint on mild or stainless steel in the overhead position. (Job Sheet 16)

*41. Set up and shut down GTAW equipment for welding aluminum. (Job Sheet 17)

*42. Prepare aluminum for GTAW. (Job Sheet 18)

*43. Prepare a tungsten electrode for welding aluminum. (Job Sheet 19)

*44. Strike and maintain an arc to make stringer beads on aluminum without filler metal in the flat position. (Job Sheet 20)

*45. Strike and maintain an arc to make stringer beads on aluminum with filler metal in the flat position. (Job Sheet 21)

*46. Weld to specifications a fillet weld lap joint on aluminum in the flat position. (Job Sheet 22)

*47. Weld to specifications a fillet weld T-joint on aluminum in the flat position. (Job Sheet 23)

*48. Weld to specifications a square-groove butt joint on aluminum in the flat position. (Job Sheet 24)

*49. Weld to specifications a fillet weld lap joint on aluminum in the horizontal position. (Job Sheet 25)

*50. Weld to specifications a fillet weld T-joint on aluminum in the horizontal position. (Job Sheet 26)

*51. Weld to specifications a fillet weld lap joint on aluminum in the vertical position. (Job Sheet 27)

*52. Weld to specifications a fillet weld T-joint on aluminum in the vertical position. (Job Sheet 28)

*53. Weld to specifications a square-groove butt joint on aluminum in the vertical position. (Job Sheet 29)

*54. Weld to specifications a fillet weld lap joint on aluminum in the overhead position. (Job Sheet 30)

*55. Weld to specifications a fillet weld T-joint on aluminum in the overhead position. (Job Sheet 31)

*The Job Sheets are located in the Student Workbook.

Information Sheet

Objective 1

Terms and definitions

a. **Amps**—The amount of current or rate of electron flow in a welding circuit

b. **Ar**—The abbreviation for argon shielding gas

c. **Balanced wave**—A high frequency AC welding machine power configuration that has negative and positive current roughly equal or balanced

d. **Cfh (cubic feet per hour)**—The standard by which the flow rate of shielding gases is measured

e. **EWP**—A tungsten electrode of 99.5% purity which has a relatively low current carrying capacity with AC power and a low resistance to contamination

f. **EWTh**—A tungsten electrode with 1% or 2% thoria added to give it greater current carrying capacity, longer life, and greater resistance to contamination

g. **EWZr**—A tungsten electrode with some zirconium oxide added to give it better performance characteristics in certain types of AC welding

h. **He**—The abbreviation for helium shielding gas

i. **Laminar flow**—A long, streamlined flow of shielding gas used to control turbulence around a weld puddle

j. **Pulsed gas tungsten arc welding (GTAW-P)**—A gas tungsten arc welding process variation in which the current is pulsed

k. **Unbalanced wave**—A high frequency AC welding machine power configuration that has either the negative or positive current stronger or unbalanced

l. **Volts**—The amount of force required to force a current through a given resistance in a welding circuit

Objective 2

GTAW machine controls and their functions

a. **High frequency**—Functions as a pilot arc to bridge the gap between the electrode and base metal and eliminates the need to scratch start the arc

b. **Post flow**—Functions to permit shielding gases to continue flowing around the electrode after the arc is extinguished to eliminate contamination of the electrode and the weld puddle as they cool

c. **Current selectors** (amperage controls)

- **Current range selector**—Provides a general range of amperage selections such as low, medium, high, or maximum, and should never be changed while welding
- **Fine adjustment current control**—Provides a specific amperage selection from minimum to high in low range, minimum to high in medium range, etc.

d. **Polarity switch**—Provides quick adjustment for desired polarity, DCEP, AC, and DCEN, and should never be changed while welding

e. **Start adjustment control (soft-start switch)**—Reduces current during starting to help eliminate burning the tungsten electrodes or burning through thin gauge metals

f. **High frequency switch**—Turns high frequency on or off, provides high frequency for continuous operation with nonferrous metals or start only for ferrous metals

g. **High frequency intensity rheostat**—Provides adjustment of intensity for start only or continuous operation

h. **Remote control switch**—Provides facility to switch to foot or hand operation or to panel operation

i. **Weld control switch**—Provides SMAW or GTAW welding source

j. **Power on-off switch**—Provides basic power input or shut-off for entire welding machine

Objective 3

The concept of pulse current and its use in GTAW

a. Some welding machines have a special setting called "PULSE MODE" or "PULSE."

b. The pulse setting is used to regulate current so that it establishes a heat-cool pattern that is in timed segments or pulses.

c. The pulsing action minimizes heat build-up in the base metals, especially thin base metals, and results in minimum distortion and better welds.

Objective 4

Types of GTAW systems and their characteristics

a. **Air cooled (dry rig)**—Usually suitable for light-duty welding that does not exceed 150 amps, but cannot be used for lengthy periods of continuous welding

b. **Water cooled (wet rig)**—Required for heavy-duty continuous welding and frequently uses antifreeze or a water-soluble oil in a self-contained system, but may use tap water as a coolant

Objective 5

Cooling system safety

a. Some systems have a fail-safe device that will not allow the welding circuit to be completed until the cooling system is functioning at a required level.

b. Some systems have water flow safety controls so that should the coolant supply diminish, the electrical power source is shut off.

c. Some systems have clear plastic tubing built into the supply lines so the circulating liquid can be monitored visually by the operator.

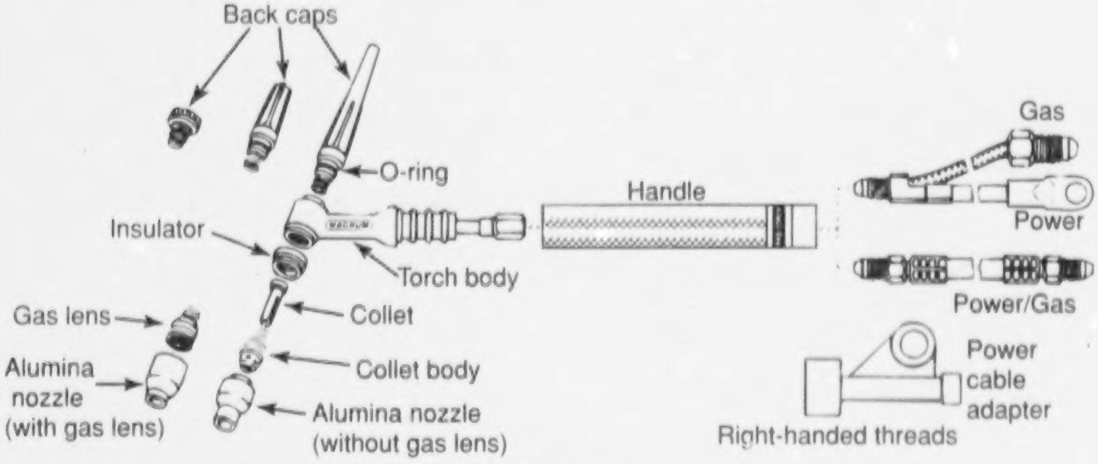
d. All systems should be checked during set-up and monitored periodically during operation to avoid damage to equipment.

Objective 6

Types of power cables and their characteristics

a. **Air cooled (gas cooled)**—These types of cables have separate gas and electric lines encased in a single insulated cover.

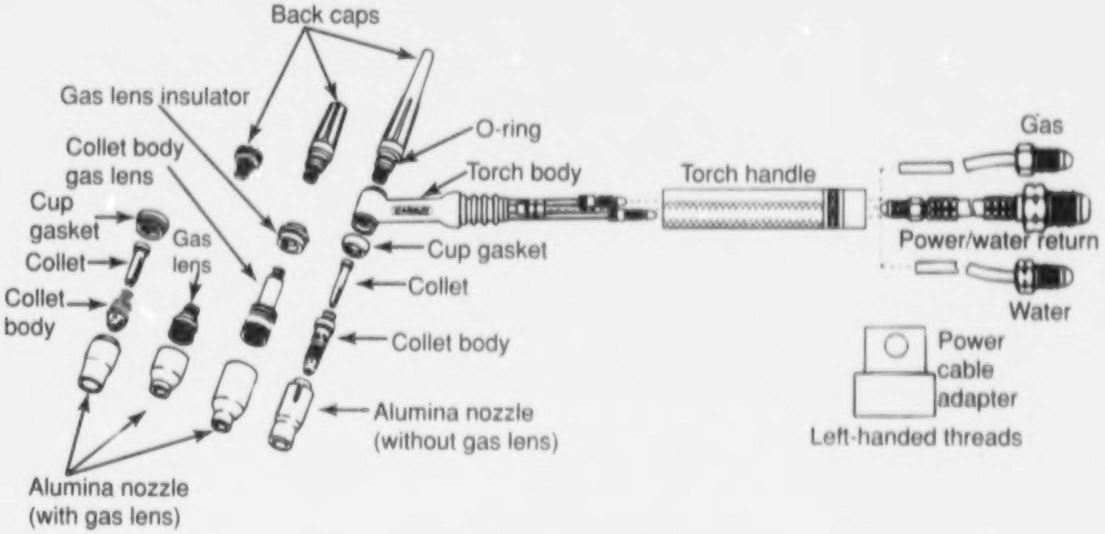
Figure 1


Back caps
O-ring
Insulator
Torch body
Handle
Gas
Power
Power/Gas
Gas lens
Collet
Collet body
Alumina nozzle (with gas lens)
Alumina nozzle (without gas lens)
Power cable adapter
Right-handed threads

Courtesy of Lincoln Electric Company.

b. **Water cooled**—These types of cables have separate gas and water-in lines and a water-out line and power cable that are separate but usually encased in a single insulated cover.

Figure 2

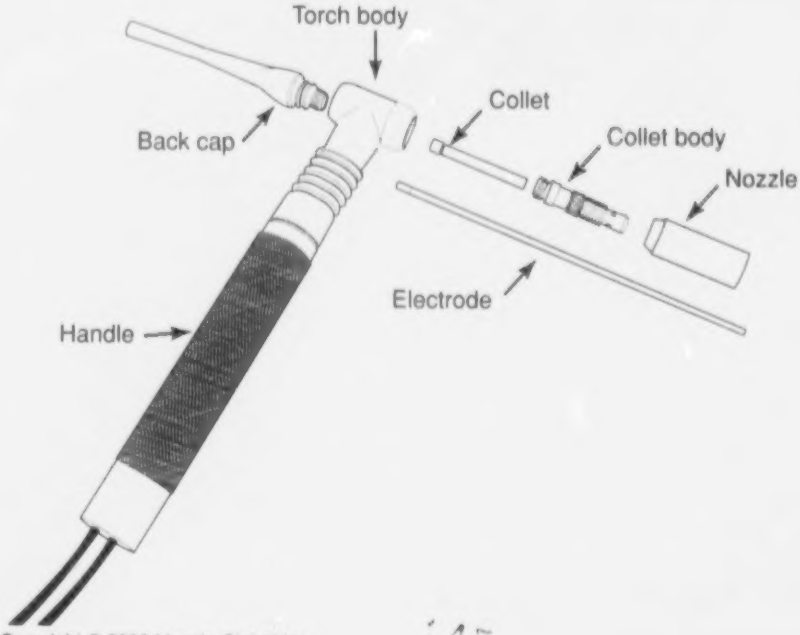

Back caps
Gas lens insulator
O-ring
Collet body gas lens
Torch body
Torch handle
Gas
Cup gasket
Gas lens
Collet
Collet body
Power/water return
Cup gasket
Collet
Water
Collet body
Power cable adapter
Alumina nozzle (without gas lens)
Left-handed threads
Alumina nozzle (with gas lens)

Courtesy of Lincoln Electric Company.

Objective 7

Parts of a GTAW torch and their functions

Figure 3


Torch body
Collet
Back cap
Collet body
Nozzle
Electrode
Handle

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a. **Alumina nozzle gas lens**—Directs the flow of inert gas around the holder and electrode and then to the weld area; threaded to accept gas lens

b. **Alumina nozzle (without gas lens)**—Directs the flow of inert gas around the holder and electrode and then to the weld area

c. **Back cap**—Holds and tightens tungsten electrode in collet

d. **Collet**—Guides, centers, and holds the electrode

e. **Collet body**—Holds collet and electrode, diffuses shielding gas, and anchors nozzle

f. **Collet body gas lens**—Holds collet and electrode; produces a longer, undisturbed flow of shielding gas and allows longer electrode extension

g. **Cup gasket**—Shields the high frequency spark; used when gas lens setup is not needed

h. **Electrode**—Acts as a nonconsumable conductor of the welding current

i. **Gas lens**—Produces a longer, undisturbed flow of shielding gas and allows longer electrode extension

j. **Insulator**—Shields the high frequency spark

k. **Nozzle**—Directs the flow of shielding gas around the electrode and into the weld zone to prevent contamination

l. **O-ring**—Prevents gas leakage

m. **Power cable adapter**—Connects torch hoses to the power source output stud

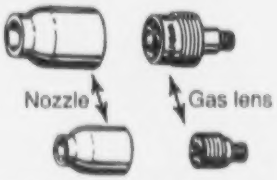
n. **Torch body**—Provides housing for electrode, collet, collet body, and fitting ends for gas and water supplies

Objective 8

The gas lens and its uses

a. A gas lens has a porous barrier diffuser with one or more fine mesh screens, and is designed to fit around the electrode or the collet.

Figure 4



Courtesy of American Torch Tip.

b. A gas lens produces a longer, undisturbed flow of shielding gas, a phenomena called "laminar flow."

c. With a gas lens, an operator can weld with the nozzle an inch or more away from the work, and improve the ability to see the weld pool.

d. Better sight of the weld pool means that an operator has better control working on inside corners or other areas with limited access.

Objective 9

Types of nozzles and their functions

a. **Ceramic**—Most commonly used nozzle because it does an adequate job and is the least expensive

b. **Fused quartz**—A clear-glass nozzle that allows a welder to see through it when good visibility of the weld zone is required

c. **Metal**—Usually copper and used where application might break other types of nozzles

d. **Alumina fused quartz**—Made of high-strength aluminum to give high impact resistance and long life

Objective 10

Steps in GTAW nozzle selection

a. Determine the type of current, DCEN, DCEP, or AC, and the amperage setting you need for the job.

b. Use the amperage setting to determine the proper electrode diameter for the job.

c. Use the electrode diameter to select the proper gas nozzle, and remember that the gas nozzle size is based on the inside diameter of the nozzle.

Recommended Tungsten Electrodes[a] and Gas Cups for Various Welding Currents

			Direct Current, A		Alternating Current, A	
Electrode Diameter		Use Gas Nozzle I.D.	Straight Polarity[b]	Reverse Polarity[b]	Unbalanced Wave[c]	Balanced Wave[c]
in.	mm	in.	DCEN	DCEP		
0.010	0.25	1/4	up to 15		up to 15	up to 15
0.020	0.50	1/4	5—20		5—15	10—20
0.040	1.00	3/8	15—18		10—60	20—30
1/16	1.6	3/8	70—150	10—20	50—100	30—80
3/32	2.4	1/2	150—250	15—30	100—160	60—130
1/8	3.2	1/2	250—400	25—40	150—210	100—180
5/32	4.0	1/2	400—500	40—55	200—275	160—240
3/16	4.8	5/8	500—750	55—80	250—350	190—300
1/4	6.4	3/4	750—1100	80—125	325—450	325—450

a. All values are based on the use of argon as the shielding gas.
b. Use EWTh-2 electrodes.
c. Use EWP electrodes.

Adapted from American Welding Society, 1991, *Welding Handbook*, Vol. 2, *Welding Processes*, Table 3.2.

Objective 11

GTAW shielding gases and their characteristics

Note: Argon and helium are the most popular inert shielding gases, but any inert gas can be used.

a. Argon (Ar)

- Produces smoother, quieter arc
- Has greater cleaning action on AC
- Is more abundant
- Costs less
- Can use lower flow rates
- Has better resistance to cross drafts

b. Helium (He)

- Has a smaller heat affected zone
- Has hotter arc than with argon (1.7 times)
- He and Ar/He mixtures are recommended for thick sections and materials having high melting temperatures
- Provides higher welding speeds

c. Hydrogen (H)

Note: The following characteristics occur when hydrogen is added to argon.

- Constricts the arc further
- Produces cleaner welds
- Provides faster travel speeds
- Deeper depth to width ratio
- Used primarily for welding austenitic stainless steels and some nickel alloys

  Note: Argon/Hydrogen mixes increase the risk of hydrogen cracking and porosity especially in multipass welds.

d. Nitrogen (N)

- Produces more energy to the work
- Excellent for welding copper

  Note: Argon/Nitrogen mixes cannot be used to weld ferrous materials due to nitrogen pick-up in the weld. This will cause the weld to lose strength and cause porosity.

Objective 12

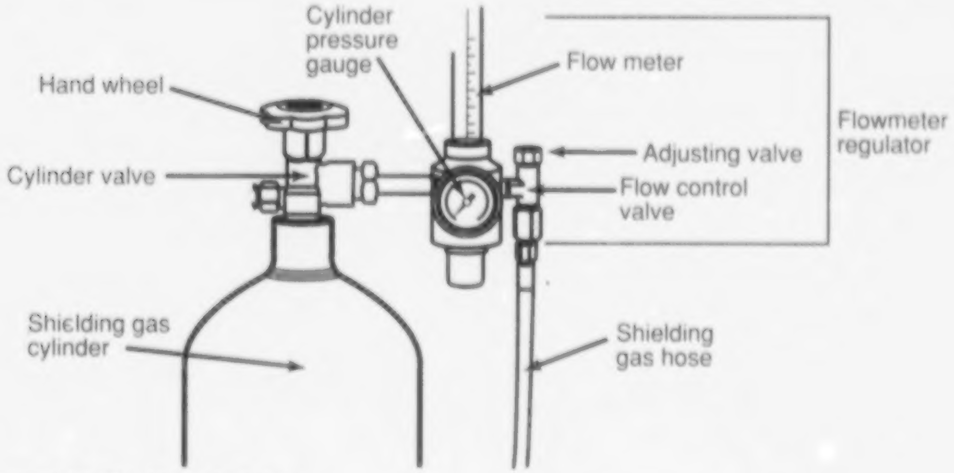
Flow meter design and use

a. Flow meters regulate the flow of low pressure gases as measured in cubic feet per hour (cfh).

b. Operate floating-ball type flow meters only in the vertical position.

c. Always use a regulator between the gas supply and the flow meter to assure uniform input pressure to the flow meter.

Figure 5


Cylinder pressure gauge
Hand wheel
Flow meter
Flowmeter regulator
Adjusting valve
Cylinder valve
Flow control valve
Shielding gas cylinder
Shielding gas hose

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d. Close the adjusting screw when first setting up a gas supply, and then turn it on slowly to make the proper cfh adjustment.

Objective 13

Flow rates for GTAW shielding gases

a. Flow rates for GTAW shielding gases vary with the type of gas, the nozzle size, and air movement in the welding environment.

b. With argon as a shielding gas, 20 cfh is an almost standard flow rate for DCEN and AC welding.

c. In general, flow rate increases in proportion to the cross-sectional area at the nozzle; this means that some flow rates could range as high as 35 cfh or as low as 15 cfh.

d. Excessive flow rates contribute to turbulence around the weld puddle and usually cause weld problems.

e. Flow rate usually has to be increased when welding in the overhead position.

Objective 14 Tungsten electrodes, their characteristics and applications

Type of Electrode	AWS	Color	Polarity	Applications
Pure	EWP	Green	AC	Aluminum, copper, and magnesium alloys
1% Thoriated	EWTh-1	Yellow	DC-	Aluminum, copper, magnesium alloys, nickel, plain carbon and low alloy steels, stainless steel, and titanium
2% Thoriated	EWTh-2	Red	DC-	Aluminum, copper, magnesium alloys, nickel, plain carbon and low alloy steels, stainless steel, and titanium
Zirconiated	EWZr	Brown	AC	Aluminum, copper and its alloys, magnesium alloys
Ceriated	EWCe-2	Orange	AC & DC-	Aluminum, copper, and magnesium alloys
Lanthanated	EWLa-1	Black	AC & DC-	Aluminum, copper, and magnesium alloys
Lanthanated	EWLa-1.5	Gold	AC & DC-	Aluminum, copper, magnesium alloys, nickel, plain carbon and low alloy steels, stainless steel, and titanium
Lanthanated	EWLa-2	Blue	AC & DC-	Aluminum, copper, magnesium alloys, nickel, plain carbon and low alloy steels, stainless steel, and titanium
Rare Earths	EWG	Gray	AC & DC-	Aluminum, copper, magnesium alloys, nickel, plain carbon and low alloy steels, stainless steel, and titanium

Information in this table is courtesy of Lincoln Electric Co. and OSRAM Sylvania.

Note: All finishes are ground or cleaned and all sizes are 1/16–1/4.

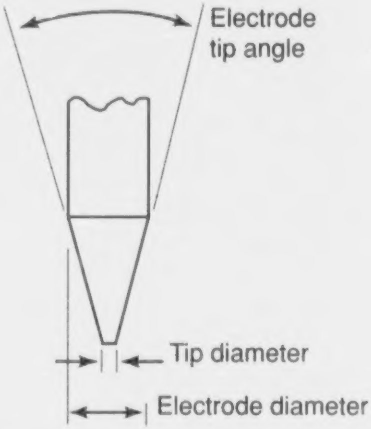
Information Sheet

Objective 15

Guidelines for preparing tungsten electrodes for DC welding

a. For DC welding on very thin metal or when using low-amperage starting, grind a tungsten electrode on a taper to a conical tip.

Figure 6


Electrode tip angle
Tip diameter
Electrode diameter

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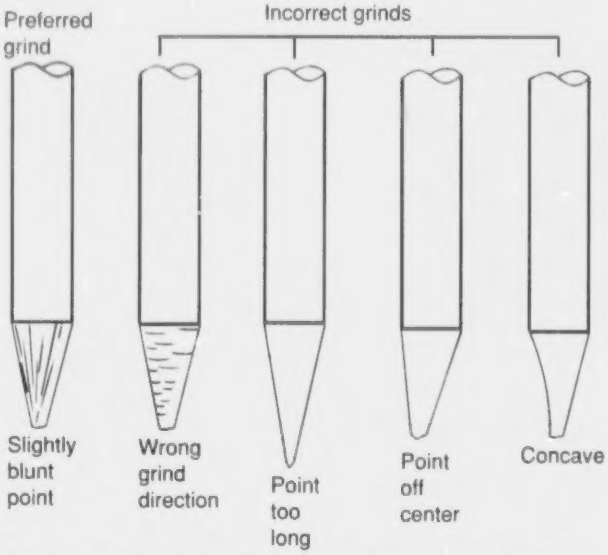
b. If there is a chance that a fine point might melt off into the weld deposit, taper the electrode to a blunt point.

Figure 7

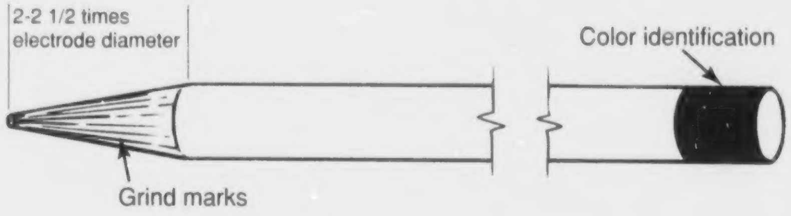

Preferred grind
Incorrect grinds
Slightly blunt point
Wrong grind direction
Point too long
Point off center
Concave

Courtesy of National Center for Construction Education and Research.

Note: Do not grind to a sharp point.

c. Grind the taper so that it is equal in length to 2 to $2^{1}/_{2}$ times the diameter of the electrode.

Figure 8



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Note: Tungsten electrodes can also be sharpened chemically by dipping a hot electrode into a container of sodium nitrate, but the process is used only in special applications.

Objective 16

Guidelines for grinding electrodes for DC welding

a. Grind tungsten electrodes on a grinding wheel reserved especially for use with tungsten in order to avoid contamination.

b. For best results, use a 120-grit grinding wheel.

c. Grind the tungsten electrode lengthwise with the grain of the electrode, not crosswise over the grain because that will restrict current flow and cause other welding problems.

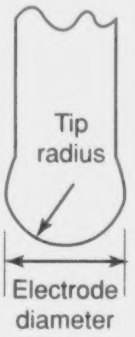
d. Position the tungsten above the wheel at an angle that permits consistent shaping without chance that the grinding surface could catch the electrode and ruin the end.

Objective 17

Guidelines for preparing tungsten electrodes for AC welding

a. Tungsten electrodes used for AC welding on aluminum require a ball tip.

Figure 9



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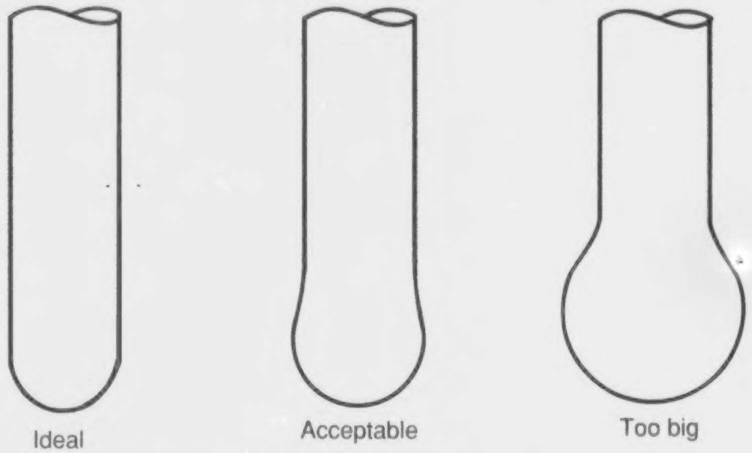
b. This "ball" is equal to 1 to 1 1/2 times the diameter of the tungsten.

c. With pure tungsten electrodes, form the ball tip by striking the electrode on aluminum and the ball will form during the welding process.

Figure 10



Courtesy of National Center for Construction Education and Research.

d. With a used or contaminated thoriated tungsten electrode, nick the electrode on a grinding wheel and break the end off with a pair of pliers and then prepare the electrode as you would a new one.

e. To form the ball on a thoriated tungsten electrode, strike the end with the clean break on a piece of copper with the high frequency control on "start only," and in reverse polarity (DCEP) with a low amp setting.

f. Smaller tungsten electrodes (0.010–0.040) are difficult to taper, but larger electrodes (1/16–1/4), both pure and thoriated tungsten, should be tapered even when the end will later be balled for AC welding.

g. The length of the taper on larger electrodes should be about twice the diameter of the electrode, and the ball end should be no more than 1 1/2 times the diameter of the electrode at the tapered end.

Objective 18

Guidelines for GTAW electrode extension

a. Several variables dictate how far a tungsten electrode should be extended from the nozzle:

- Type of welding, DCEN, DCEP, or AC
- Metal thickness
- Joint design

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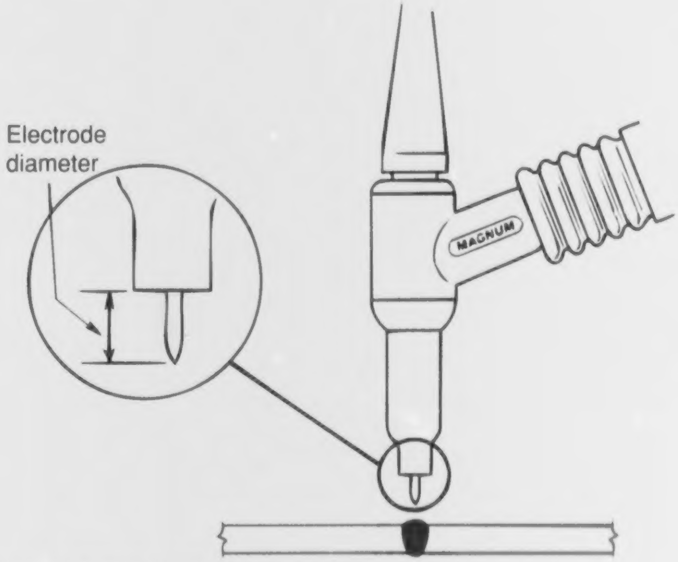
- Welding position

Figure 11



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b. One general rule is to make electrode extension as short as possible to improve shielding.

c. Another general rule is that proper electrode extension should give good penetration and shielding, and still provide the operator with a functional view of the weld puddle.

d. Fillet welds almost always require a longer electrode extension than butt welds.

e. Develop the habit of starting with an electrode extension of about $^{1}/_{8}$″ and then adjusting the extension as welding continues.

Objective 19

Guidelines for filler metal selection and use

Note: See Student Supplement 1 for more information on filler metals.

a. Select a filler metal that is compatible with the base metal.

b. Select the type and size of filler metal according to the type and thickness of the base metal.

c. Keep filler metals clean and free of contamination whether in use or in storage.

d. Do not remove the hot end of the filler wire or rod from the protection of the gas-shielded zone during the welding operation.

Objective 20

Requirements for base metal preparation

a. Remove mill scale, dirt, and paint from all surfaces with a sander/grinder.

b. Remove normal surface oxides with a stainless steel brush.

c. Remove heavy oxides, grease, and oil with a shop rag wet with a combination cleaner that will degrease and deoxidize at the same time.

d. If you use solvents for cleaning, allow them to dry before welding starts.

> **Caution:** Many solvent cleaners and deoxidizers are highly flammable and should be used with care.

e. Fit-up is critical in GTAW, so make joint preparation uniform with no irregularities or gaps.

f. Begin welding as soon as possible after the base metal has been prepared to eliminate the chance of airborne contaminants adhering to the metal.

Objective 21

Special problems with contamination and air movement

a. Metals that are not properly cleaned before welding starts will immediately contaminate a tungsten electrode, make welding difficult or impossible, and waste valuable time.

b. Work areas that are unclean will add to the potential for contaminants to slow or stop the welding process.

c. Air movement across the weld zone blows the shielding gas away and contributes to immediate contamination of the weld zone.

d. Work areas should be checked for drafts and cross ventilation that could blow shielding gas away, and screens or deflectors should be erected around the work area as needed.

Objective 22

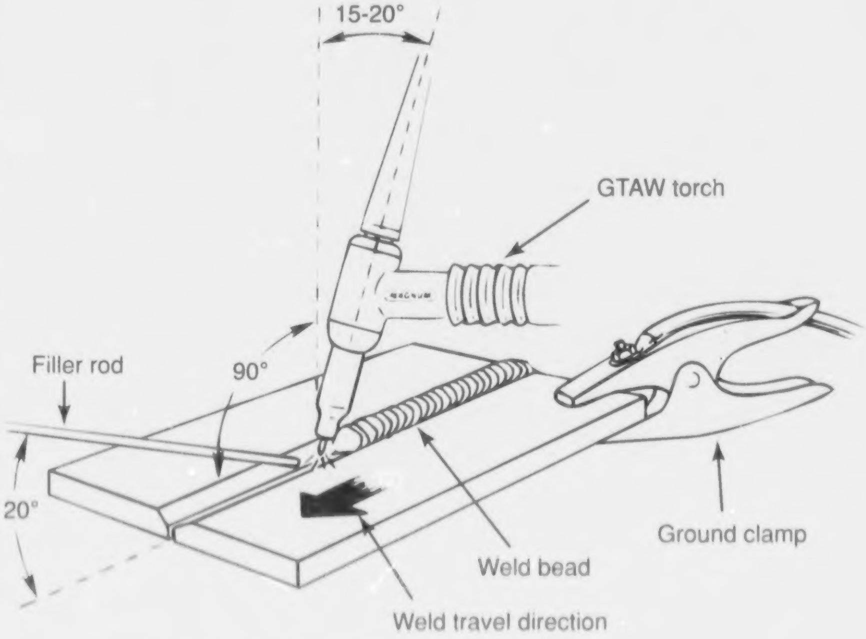
Steps for manual welding with a filler rod

a. Select and prepare tungsten electrode, adjust electrode extension, and adjust machine controls.

b. Move the torch so that tungsten electrode comes within $^{1}/_{8}''$ to $^{1}/_{16}''$ of the base metal, strike arc and adjust to desired length.

c. Hold the torch at a 15–20° angle to the base metal and make very slight circular motions until a bright, fluid puddle forms.

Figure 12


15-20°
GTAW torch
Filler rod
90°
20°
Ground clamp
Weld bead
Weld travel direction

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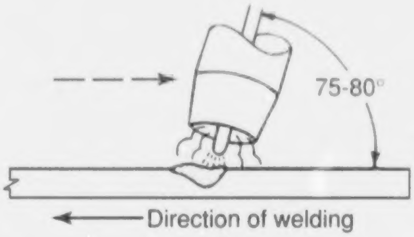
d. Move the torch back from the puddle away from the direction of travel and angle it at 75–80°.

Figure 13


75-80°
Direction of welding

Courtesy of Lincoln Electric Company.

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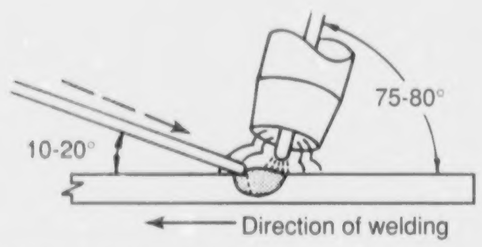
e. Insert the filler metal rod at a 10–20° angle into the leading edge of the molten pool and let a drop or two of molten metal fill the puddle.

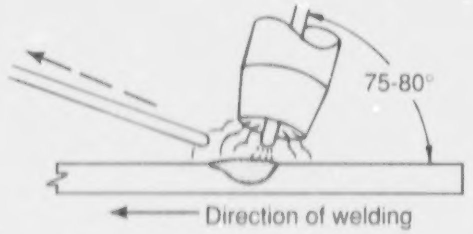
Figure 14


75-80°
10-20°
Direction of welding

Courtesy of Lincoln Electric Company.

f. Withdraw the filler rod from the puddle, but be sure to keep the end of the rod in the shielded zone.

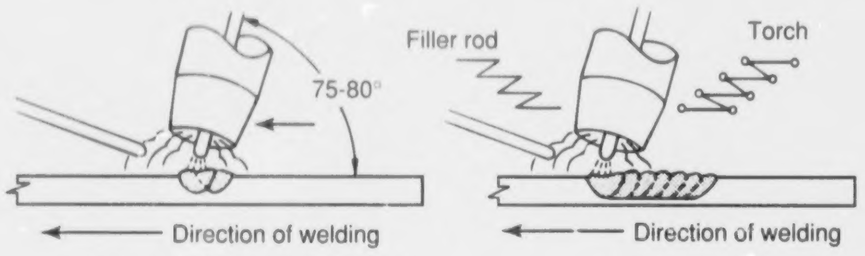
Figure 15


75-80°
Direction of welding

Courtesy of Lincoln Electric Company.

g. Move torch back to the leading edge of the puddle and repeat the procedure.

Figure 16


75-80°
Direction of welding
Filler rod
Torch
Direction of welding

Courtesy of Lincoln Electric Company.

Objective 23

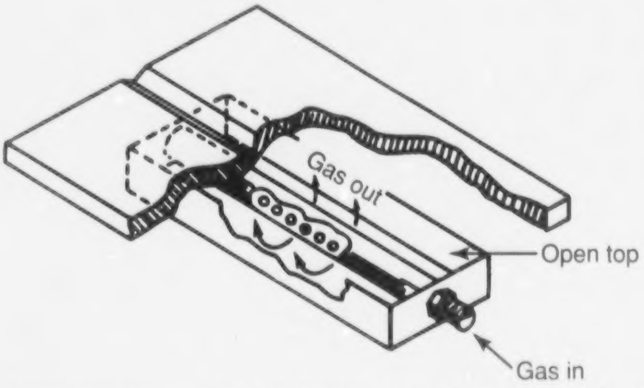
Backup bars and their use in GTAW

a. On certain GTAW applications, backup bars (normally copper) may be required to physically support the joint and the weld puddle.

b. Backup bars also serve to protect the backside of a weld from contamination and to "chill" or draw heat away from the weld zone.

c. In pipe welds and groove welds, welded from one side only, a purging gas should be directed to protect the back side of the weld from contamination.

Figure 17



Adapted from American Welding Society, 1991, *Welding Handbook*, Vol. 2, *Welding Processes*, Figure 3.16.

Objective 24

Guidelines for troubleshooting GTAW problems

a. Try to isolate electrical or mechanical problems from process problems.

Example: Contamination in a weld could be caused by improper electrode preparation, but it might also be caused by an improper flow rate of shielding gas.

b. Check the workplace for air movement or drafts that could be causing problems with shielding.

c. Change only one variable at a time so you can use a logical process of elimination instead of creating a totally different problem.

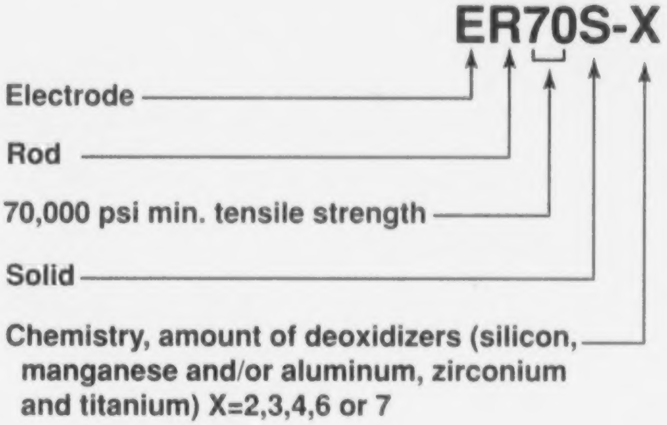
d. Observe all safety rules when troubleshooting, especially when troubleshooting electrical problems.

Note: See Student Supplement 3 for GTAW troubleshooting guidelines from the American Welding Society. Student Supplement 2 contains valuable reference information for evaluating good and poor welds with materials from Miller Electric Mfg. Co.

Student Supplement 1—Filler Metals

AWS Filler Metal Classification*

*Classified by AWS with GMAW wires because they both use the same wire chemical compositions


ER70S-X
Electrode
Rod
70,000 psi min. tensile strength
Solid
Chemistry, amount of deoxidizers (silicon, manganese and/or aluminum, zirconium and titanium) X=2,3,4,6 or 7

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Student Supplement 1

Cut Length Consumables

Carbon Steel GTAW

- ER70S-2
  - Triple deoxidized rod (Si, Mn, Al, Zr, Ti)
  - Produces X-ray quality welds over most surface conditions
  - Allows welding on some rust, scale, and dirt
  - Less fluid pool for out-of-position welding
- ER70S-3
  - High quality rod with intermediate levels of Mn and Si
  - For general fabrication on clean steel
- ER70S-6
  - High quality rod with higher Mn and Si levels
  - Improved mechanical properties and bead appearance
  - Higher hardness

Stainless Steel GTAW

- ER308/308L
  - For joining common austenitic stainless steels
  - Grades referred to as "18-8" steels
  - Typical alloys: ASTM 303, 304 or A743
- ER309/309L
  - For joining higher alloyed austenitic stainless steels
  - Overmatches the corrosion resistance of "18-8" steels
  - Typical alloys: ASTM A240, 309S or A774
- ER316/316L
  - For high crack resistance and cladding
  - Undiluted weld metal can be used on "18-8" steels
  - Typical alloys: ASTM A240, 316L or A773

Aluminum GTAW

- ER4043
  - Aluminum alloyed with silicon
  - Designed to weld heat-treatable aluminum alloys in the "6000" series
  - Not suitable to weld aluminum-magnesium
- ER5356
  - Aluminum alloyed with magnesium
  - Most commonly used aluminum filler alloy
  - Good strength and compatibility with most alloys
  - Not suitable for applications with service temperatures exceeding 150° F

Silicon Bronze

- ERCuSi-A
  - Copper/Silicon alloy for welding
    - Copper
    - Brass
    - Bronze

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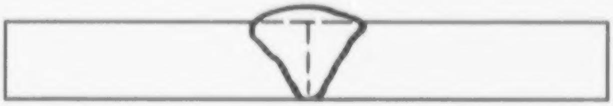
Student Supplement 2—Evaluating Good Welds and Poor Welds

Evaluating Good Welds

1. Examine the weld for proper build-up with good penetration and bead edges fused in.
2. Look for a weld that is clean and bright with an even ripple and a smooth edge.
3. On a butt weld, look for uniform width and correct bead size.

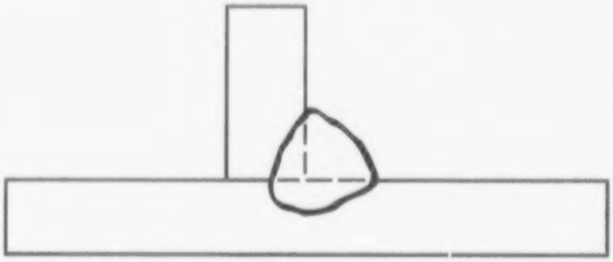
Figure 1



Courtesy of Miller Electric Mfg. Co.

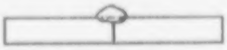
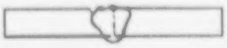
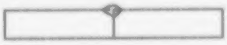
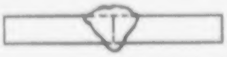
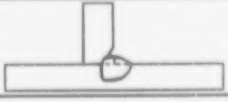
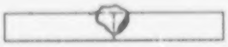
4. On a fillet weld, look for the legs of the fillet to equal the metal thickness.
5. On a fillet weld, look for no undercutting and a bead face that is slightly convex.

Figure 2



Courtesy of Miller Electric Mfg. Co.

Student Supplement 2

Problem	Appearance	Cause
Excessive build-up Poor penetration Poor fusion at edges		Welding current too low
Bead too wide and flat Undercut at edges Excessive burn through		Welding current too high
Bead too small Insufficient penetration Ripples widely spaced		Travel speed too fast
Bead too wide Excessive build-up Excessive penetration		Travel speed too slow
Undercut Insufficient weld deposit Uneven penetration		Welding current too high and/or wrong placement of filler rod
Poor penetration Poor fusion		Faulty joint preparation and too low welding current

Courtesy of Miller Electric Mfg. Co.

Student Supplement 3—Troubleshooting Guide for Gas Tungsten Arc Welding

Problem	Cause	Remedy
Excessive electrode consumption	1. Inadequate gas flow. 2. Operating on reverse polarity. 3. Improper size electrode for current required. 4. Excessive heating in holder. 5. Contaminated electrode. 6. Electrode oxidation during cooling. 7. Using gas containing oxygen or CO_2.	1. Increase gas flow. 2. Use larger electrode or change to straight polarity. 3. Use larger electrode. 4. Check for proper collet contact. 5. Remove contaminated portion. Erratic results will continue as long as contamination exists. 6. Keep gas flowing after stopping arc for at least 10 to 15 seconds. 7. Change to proper gas.
Erratic arc	1. Base metal is dirty, greasy. 2. Joint too narrow. 3. Electrode is contaminated. 4. Arc too long.	1. Use appropriate chemical cleaners, wire brush, or abrasive. 2. Open joint groove; bring electrode closer to work; decrease voltage. 3. Remove contaminated portion of electrode. 4. Bring holder closer to work to shorten arc.
Porosity	1. Entrapped gas impurities (hydrogen, nitrogen, air, water vapor). 2. Defective gas hose or loose hose connections. 3. Oil film on base metal.	1. Blow out air from all lines before striking arc; remove condensed moisture from lines; use welding grade (99.99%) inert gas. 2. Check hose and connections for leaks. 3. Clean with chemical cleaner not prone to break up in arc; DO NOT WELD WHILE BASE METAL IS WET.
Tungsten contamination of workpiece	1. Contact starting with electrode. 2. Electrode melting and alloying with base metal. 3. Touching tungsten to molten pool.	1. Use high frequency starter; use copper striker plate. 2. Use less current or larger electrode; use thoriated or zirconium-tungsten electrode. 3. Keep tungsten out of molten pool.

Adapted from American Welding Society, 1991, *Welding Handbook*, Vol. 2, *Welding Processes*, Table 3.6.

Unit 3

Plasma Arc Cutting

Unit Contents

Student Components

Student Page

Learning Activities Sheet 3–3

Objective Sheet 3–5

Information Sheet 3–7

*Job Sheets

1—Prepare a PAC Machine for Operation 113
2—Complete a Contact Cut on Selected Metal 115
3—Complete a Stand-Off Cut on Selected Metal 117
4—Gouge Mild Steel Plate With a PAC Unit 119

*The Job Sheets are located in the Student Workbook.

Prerequisites:
None

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 through 3.

Optional

☐ 4. **View** Videotape entitled *Plasma Cutting and Gouging.*

☐ 5. **Study** Information Sheet, Objectives 4 through 6.

Optional

☐ 6. **View** Videotapes entitled *Hearing Conservation* and *Eye Protection A New Approach.*

☐ 7. **Study** Information Sheet, Objectives 7 and 8.

☐ 8. **Research** Online resources regarding plasma arc cutting. Visit www.hypertherm.com as one of your sources.

☐ 9. **Study** Information Sheet, Objectives 9 through 16.

☐ 10. **Observe** Demonstration of procedures to be used in completing Job Sheet 1.

☐ 11. **Do** Job Sheet 1, "Prepare a PAC Machine for Operation."

☐ 12. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 13. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat steps 9 through 11.

☐ 13. **Study** Information Sheet, Objectives 17 through 19.

☐ 14. **Observe** Demonstration of procedures to be used in completing Job Sheet 2.

Learning Activities Sheet

☐ 15. **Do** Job Sheet 2, "Complete a Contact Cut on Selected Metal."

☐ 16. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 17. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat steps 13 through 15.

☐ 17. **Observe** Demonstration of procedures to be used in completing Job Sheet 3.

☐ 18. **Do** Job Sheet 3, "Complete a Stand-Off Cut on Selected Metal."

☐ 19. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 20. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat steps 13, 17, and 18.

☐ 20. **Study** Information Sheet, Objectives 20 through 22.

☐ 21. **Observe** Demonstration of procedures to be used in completing Job Sheet 4.

☐ 22. **Do** Job Sheet 4, "Gouge Mild Steel Plate With a PAC Unit."

☐ 23. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 24. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 4 and repeat steps 20 through 22.

☐ 24. **Check** With instructor for any additional assignments to be completed.

☐ 25. **Do** Additional assignments listed below.

____

____

____

☐ 26. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 27. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

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Objective Sheet

Unit Objective

After completing this unit, the student should be able to prepare a PAC machine for operation and use a PAC system to make a contact cut, a stand-off cut, and to gouge mild steel. The student should demonstrate these competencies by completing the job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to plasma arc cutting with their definitions.
2. Complete statements concerning basic characteristics of plasma arc cutting.
3. Match basic components with their functions in an air cut PAC system.
4. Select true statements concerning plasma arc electrical safety.
5. Complete statements concerning plasma arc environmental safety.
6. Solve problems concerning plasma arc workplace safety.
7. Select true statements concerning advantages of plasma arc cutting.
8. Select true statements concerning characteristics of plasma arc transfer modes.
9. Solve problems concerning guidelines for PAC electrode selection.
10. Select true statements concerning guidelines for cutting nozzle selection and installation.
11. Solve problems concerning shielding cups, their design and uses.
12. Select true statements concerning plasma air and secondary air used with PAC.
13. Solve problems concerning PAC consumables, their characteristics and maintenance.
14. Solve problems concerning PAC system duty cycles.
15. Select true statements concerning guidelines for setting PAC flow rate and flow pressure.
16. Solve problems concerning guidelines for using compressed air with a PAC system.
17. Select true statements concerning factors affecting cutting speeds.

Objective Sheet

18. Select true statements concerning techniques for contact and stand-off cutting.

19. Select true statements concerning techniques for cutting expanded metal.

20. Solve problems concerning techniques for gouging metal.

21. Select true statements concerning techniques for piercing and beveling metal.

22. Match cutting problems with their probable causes.

*23. Prepare a PAC machine for operation. (Job Sheet 1)

*24. Complete a contact cut on selected metal. (Job Sheet 2)

*25. Complete a stand-off cut on selected metal. (Job Sheet 3)

*26. Gouge mild steel plate with a PAC unit. (Job Sheet 4)

*The Job Sheets are located in the Student Workbook.

Information Sheet

Objective 1

Terms and definitions

a. **Cfh (Cubic feet per hour)**—The measurement of flow in an environment where temperature and pressure are not held to a standard

b. **CNC (Computerized Numerical Controls)**—Machines that have high travel speeds required to produce good quality cuts and have a high volume of production; operator can input instructions such as speed, current, gas flow, location and shape of part to be cut

c. **Consumables**—Materials or components that are used up during a process

d. **Contact cutting**—A hand cutting technique that requires holding a torch at a slight angle and keeping the torch in contact with the workpiece as a cut is made

e. **Hafnium**—A metallic element in PAC electrodes that are used for cutting with air or oxygen

f. **Pilot arc**—The arc initiated *inside* a PAC torch when a cutting gas encounters electrical energy in a nozzle

g. **Plasma arc**—The arc created *outside* a PAC torch between the nozzle and the workpiece

h. **Safety interlocks**—Control devices that shut off a plasma torch when cutting air falls below a minimum pressure or when torch or machine components overheat

i. **Scfh (Standard cubic feet per hour)**—The measurement of flow in an environment where temperature and pressure are held to standards of temperature and pressure

Example: 70°F and pressure at sea level

j. **Stand-off cutting**—A hand or machine cutting technique in which the plasma torch is held perpendicular to and about 1/8″ above the workpiece as the cut is made

k. **Trigger switch**—The switch or button on a PAC torch that initiates the flow of cutting gas into a plasma arc nozzle

Information Sheet

Objective 2

Basic characteristics of plasma arc cutting

a. The "plasma" in plasma arc cutting is formed when constricted shop air or gas flows through the arc of a high temperature electrode.

b. The plasma becomes "ionized" or electrically conductive and transfers a high temperature electric arc through a nozzle to a workpiece.

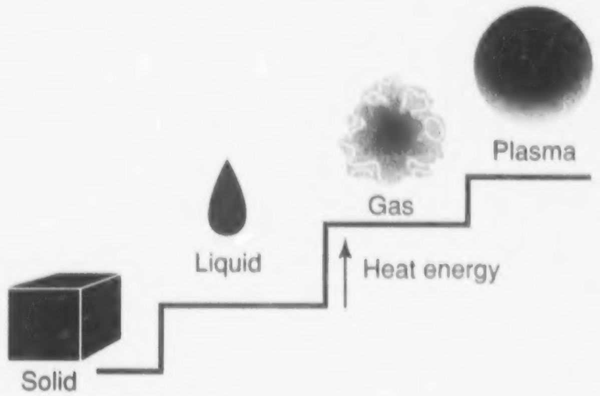
c. When the tip of a plasma arc torch is brought close to or in contact with a workpiece, the plasma stream produces a stiff, constricted cutting arc.

d. The orifice in the torch nozzle directs the plasma stream to the workpiece where it superheats a small area of the workpiece to a temperature so high that cutting can begin with no preheating.

e. As the arc melts the workpiece, the high-velocity jet blows away molten metal to form the kerf or cut.

Note: Plasma is described as the fourth state of matter. By adding energy to a gas, the temperature and electrical characteristics change through a process called ionization. As ionization takes place, the plasma created becomes electrically conductive and free electrons are available to carry current.

Figure 1



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Objective 3

Basic components and their functions in an air cut PAC system

a. **PAC machine**—A portable wheel-mounted control cabinet housing electrical components, pressure safety control, electrical overload control, and an air valve assembly

b. **Regulator assembly**—An assembly that contains the pressure regulator for adjusting shop air in p.s.i. (pounds per square inch)

c. **Filter assembly**—An assembly that filters compressed shop air so that it will be free of oil and water

d. **Torch lead assembly**—A three-lead cable used to connect the torch to a gas supply, a power source, and a torch trigger interface

e. **Torch**—A handheld device which houses the torch head, the electrode, cutting nozzle, shield cup, and trigger switch

Objective 4

Plasma arc electrical safety

a. A plasma arc system must not exceed the amperage ratings of the fuse or breaker of the source power supply.

b. Since system power may vary from 150v to 400v, power leads into a PAC system have to be attached to the correct lugs to avoid erratic performance and possible damage to components.

c. When using an extension cord with a PAC machine, make sure the cord has the proper wire gauge for its length.

Note: The longer the extension cord, the lower the wire gauge needs to be.

d. Always disconnect the power source from the PAC machine before making any internal adjustments or performing troubleshooting.

e. Never permit any part of your body to come in contact with the workpiece when cutting with a PAC system.

Objective 5

Plasma arc environmental safety

a. Moisture on human skin decreases electrical resistance and increases the potential for severe shock, so never use a plasma arc system in damp, wet areas.

b. Wear earplugs or muffs for protection when plasma arc cutting because the process produces high noise levels.

c. Infrared/ultraviolet rays produced by the PAC process are hazardous, so always wear an approved filter lens, at least a number nine shade to protect your eyes.

Recommended Eye Protection for Plasma Arc Cutting

Cutting Current Amperes	Lens Shade Number
Up to 300	9
300–400	12
400–800	14

Adapted from American Welding Society, 1991, *Welding Handbook*, Vol. 2, *Welding Processes*, Table 15.3.

d. Rays that pose danger to your eyes can also burn your skin, and so can molten metal or sparks, so wear gloves, an apron, safety shoes, and safe clothing as the job requires.

Information Sheet

e. Perform PAC in open, well ventilated areas, and always check confined areas for explosive and toxic gases before cutting starts.

f. Never cut in an area that contains combustible vapors, flammable liquids, or explosive dust, and NEVER cut into tanks or closed containers that have held hazardous materials.

Objective 6

Plasma arc workplace safety

a. A workplace for plasma arc cutting must have a fireproof floor.

b. Work benches used for cutting must have fireproof tops.

c. Erect heat shields or barriers to protect nearby walls and unprotected floor space from flying sparks and hot metal.

d. Combustible materials that can be moved should be moved safely away from the cutting area.

Objective 7

Advantages of plasma arc cutting

a. PAC systems have extremely fast cutting speeds when compared to oxyfuel cutting, or sawing or grinding.

b. Oxyfuel cutting is pretty much confined to carbon steels, but PAC works well with all ferrous and nonferrous metals that are electrically conductive.

Note: Electrically conductive nonferrous metals include aluminum, stainless steel, brass, nickel, and copper.

c. Because PAC requires no preheating, the cost of fuel gas is minimized and the cutting process is accelerated.

d. No preheating combined with high speed minimize the heat-affected zone and helps control distortion.

e. The cost of fuel gases can be eliminated because PAC can operate with air from a shop air compressor.

Note: Gases other than air are used in several PAC applications.

f. PAC systems are highly portable and effectively used for everything from indoor maintenance to open-air construction.

g. PAC systems have the ability to make stacked cuts.

Objective 8

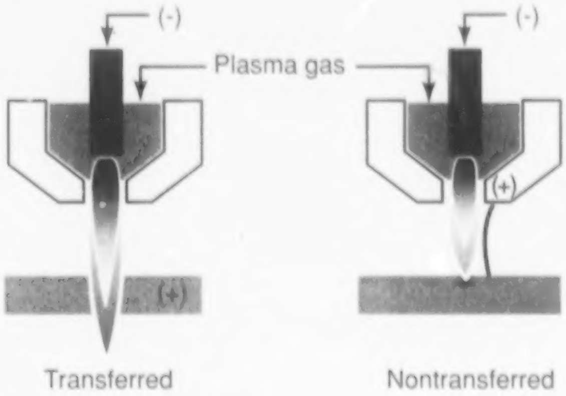
Characteristics of plasma arc transfer modes

a. The plasma jet formed in a PAC torch can be operated in either the transferred mode or the nontransferred mode.

b. In the nontransferred mode, the electric current first flows between the electrode and the torch nozzle and when the torch strikes or comes close to the workpiece, the arc transfers to the workpiece.

c. In the transferred mode, the most commonly used mode, the electric current flows directly between the electrode and the workpiece when the torch strikes or comes close to the workpiece.

Figure 2



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d. Some systems employ a pilot arc to initiate plasma transfer or to restart the arc automatically when electrical contact with the workpiece is interrupted.

e. The pilot arc enables a plasma torch to cut through grating or expanded metal without the operator having to restart the torch time after time, and it also saves wear and tear on consumables.

f. A high frequency pilot arc is used for applications where a torch has to cut through paint, rust, oil, and scale, a condition where the transferred mode could not be initiated.

Note: The high frequency pilot arc is used often in autobody repair where an operator often cuts through paint, rust, or oil.

Objective 9

Guidelines for PAC electrode selection

a. An important factor in selecting an electrode for PAC is the primary or cutting gas that will be used.

b. With PAC systems using nitrogen as a cutting gas, use 2% thoriated or zirconiated electrodes.

c. Do not use a tungsten electrode for PAC when air or oxygen are used as a cutting gas because tungsten deteriorates rapidly in air or oxygen.

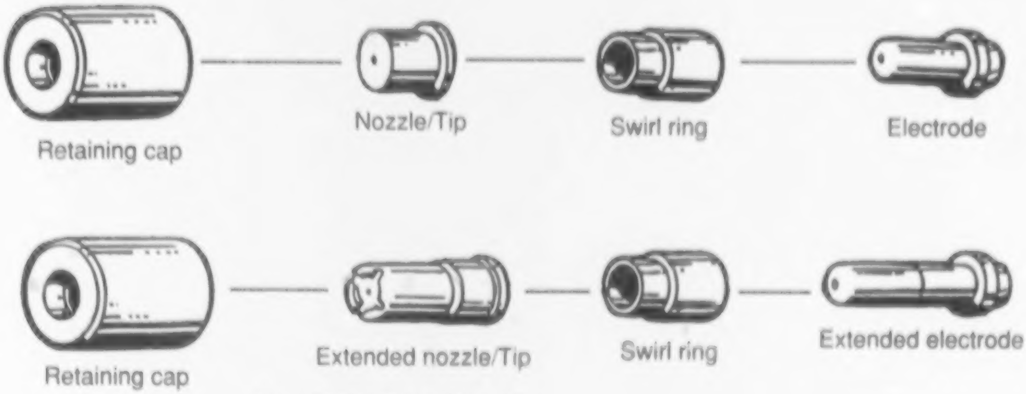
d. Low amperage, dual-flow PAC systems all use a hafnium electrode inserted or embedded in a copper casing because it wears well with air or oxygen as a cutting gas.

e. The copper casing affords a housing that can be threaded on one end and shaped on the other end so it can be removed or installed with ease, and the copper has excellent electrical characteristics.

f. Hafnium has electrical characteristics that help it absorb ions; this makes it an ideal electrode for ionizing the cutting gas which becomes a plasma.

g. Some PAC systems have extended electrodes designed for cutting in hard-to-reach places like the web of an I-beam or the inside corner of a box; these electrodes require an extended nozzle.

Figure 3



Courtesy of American Torch Tip.

h. Electrodes are rated for use with specific amperage ranges; change to the recommended electrode before changing amperage range.

Objective 10

Guidelines for cutting nozzle selection and installation

a. Just like electrodes, cutting nozzles (tips) are designed for specific amperage ranges; change to the recommended cutting nozzle before changing amperage range.

b. A cutting nozzle is sized according to the diameter of its orifice, and the size is stamped or laser imprinted on the nozzle.

c. Depending on the manufacturer, the orifice size may be stated in thousandths of an inch for smaller electrodes, fractions of an inch for larger electrodes, or millimeters.

Orifice Conversion Chart

Inches	Millimeters
.025	1.0
.030	1.2
.035	1.4
.040	1.6
.045	1.8
1/8	3.0
1/4	6.0
3/8	9.0
3/4	18.0
1	25.0

Note: Larger orifices are used for machine cutting on thicker metals.

d. Always check the manufacturer's recommended orifice size for the power range, the type and thickness of metal being cut, and the recommended cutting speed.

e. Change or install cutting nozzles with the proper tools, and tighten nozzles until they are snug, but do not overtighten.

Note: Some PAC systems have nozzles that can be removed and tightened by hand.

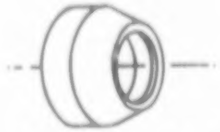
Objective 11

Shielding cups, their design and uses

a. Shielding cups protect torch components from damage, confine the secondary gas to help remove metal from the cut, and help cool torch components.

b. For contact cutting, a standard shield cup has a beveled edge that permits the operator to maintain a slight cut angle and to move the torch with ease and accuracy while maintaining contact with the workpiece.

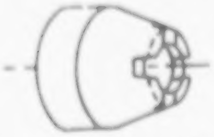
Figure 4



Courtesy of Thermal Dynamics/Division of Thermadyne.

c. For stand-off cutting, a crown shield cup has an extended bevel edge to provide the required distance for stand-off cutting at a 90° angle; notches in the crown shield permit gases and smoke to escape, and the operator can still rest the shield on the workpiece to improve the ease and accuracy of cutting.

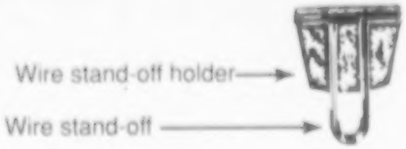
Figure 5



Courtesy of Thermal Dynamics/Division of Thermadyne

d. Another device designed for stand-off cutting is a wire stand-off assembly which provides stand-off distance with a wire placed over an unbreakable Teflon® holder.

Figure 6

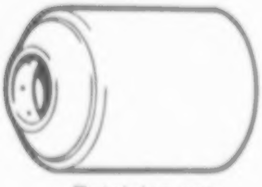


Courtesy of Smith Equipment

e. Another shielding device is a metal retaining cap covered with a high-impact plastic to promote longer consumable life.

Note: The retaining cap is used on PAC systems manufactured by Hypertherm, Inc.

Figure 7



Retaining cap

© Copyright Hypertherm, Inc.

Objective 12

Plasma air and secondary air used with PAC

a. The air that is fed into a PAC torch to be ionized and ejected to form the plasma that cuts through a workpiece is called plasma air or cutting air.

b. The air that is fed into a PAC torch and channeled around the nozzle to provide cooling and help remove metal from the cut is called secondary air or shielding air.

c. In PAC systems that use a coolant, the coolant takes the place of secondary air; the coolant (often water) is injected through the torch to help cool components and restrict the arc.

d. Nitrogen is a popular plasma or cutting gas with PAC systems, and is often used in combination with other gases for secondary air; air or oxygen for cutting mild steel, carbon dioxide for cutting stainless steel, and argon/hydrogen for cutting aluminum.

e. The plasma air and the secondary air can be the same, and is in common use with lower amperage PAC systems that use filtered, compressed shop air for both cutting and shielding.

Note: The job sheets in this unit assume that the student will be working with a PAC system that uses compressed air with a dual-flow torch.

f. Oxygen should not be used as cutting air with a system that has used compressed air unless the compressed air system has been carefully cleaned.

Objective 13

PAC consumables, their characteristics and maintenance

a. With a PAC system, the consumables are usually anything that fits onto or into the plasma torch.

b. Electrodes, cutting nozzles, and shield cups are the items most subject to deterioration.

Note: You should start your cuts on the edge of the hole to increase the life of consumables.

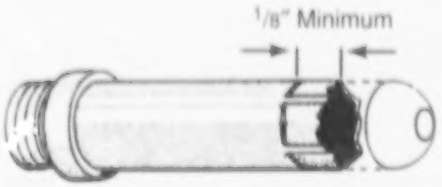
c. To check for shielding cup wear, look for worn, cracked, or burned areas that would interfere with proper performance, and replace as required.

d. To check for cutting nozzle wear, unscrew the nozzle and look for an elongated or oversized orifice, and replace as required.

e. To check for electrode deterioration, unscrew the electrode and check the condition of the face of the electrode.

f. If less than 1/8" remains on the hex area of the electrode, replace the electrode.

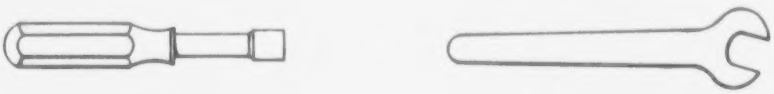
Figure 8



Courtesy of Thermal Dynamics/Division of Thermadyne.

g. Always use the tools shipped with the unit to remove and replace consumables; Thermal Dynamics systems have a wrench to remove nozzles and a nut driver to remove and replace electrodes.

Figure 9



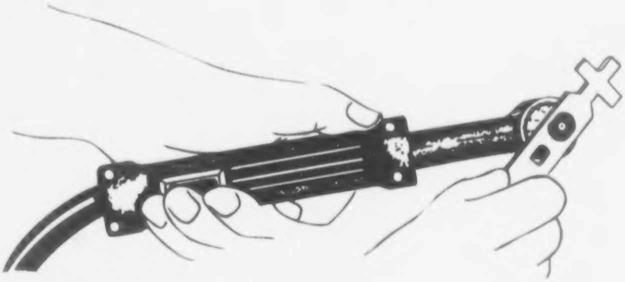
7/32" Nutdriver

7/16" Nozzle wrench

Courtesy of Thermal Dynamics/Division of Thermadyne.

h. Smith Equipment systems have a key safety wrench to remove consumable parts; the wrench is attached to a key so that when the key (and wrench) are extracted from the control panel, power to the torch is shut off to assure operator safety.

Figure 10



Courtesy of Smith Equipment.

i. Consumables on Hypertherm systems can be removed and retightened by hand; a microswitch in the retaining cap cuts off power to the torch as the cap is removed.

j. A rule of thumb for replacing consumables is to tighten components until they are snug; never overtighten.

Objective 14

PAC system duty cycles

a. As with other welding machines, PAC systems have duty cycle ratings which specify the amount of time a given load may be applied to a power source without overheating the internal components.

b. The duty cycle reference period for all welding machines is a ten-minute interval.

Example: If a 40/80 unit is rated at 100% duty cycle for the 40 amp output setting, the power source can supply a 40 amp output load for 100% of the time. In other words, it can run continuously with the use of an internal fan, it does not have to be shut down to cool. On the other hand, if the 80 amp output of the unit had a 60% duty cycle, it should be used for only six minutes and then allowed to cool for four minutes.

c. When a duty cycle is exceeded, thermal sensors in the unit shut off power to automatically protect components, and the shutdown is indicated by an illuminated fault light on the control panel.

d. When a system shuts down after exceeding the duty cycle, don't panic and unplug the source power, instead, leave power on so the fan will continue to run and cool the system.

Objective 15

Guidelines for setting PAC flow rate and flow pressure

a. Flow rate for PAC systems is expressed in Scfh (standard cubic feet per hour) and flow pressure is expressed in p.s.i. (pounds per square inch) or p.s.i.g. (pounds per square inch gauge).

b. Flow rate in Scfh is different from flow rate in cfh in that Scfh references a standard.

Example: A supply of compressed air at 70 p.s.i. should provide pressure enough to make the air flow at a rate of 270 Scfh.

c. The important thing to remember about flow pressure is to keep the p.s.i. at the pressure recommended by the equipment manufacturer.

d. Flow pressure in a PAC system may sometimes vary as much as ten pounds plus or minus without affecting the equipment, but pressure too high will quickly deteriorate an electrode, and pressure too low will quickly deteriorate a cutting nozzle.

e. All PAC systems have safety interlocks that shut the PAC machine off if flow pressure drops below a minimum point, usually around 40 p.s.i.

Objective 16

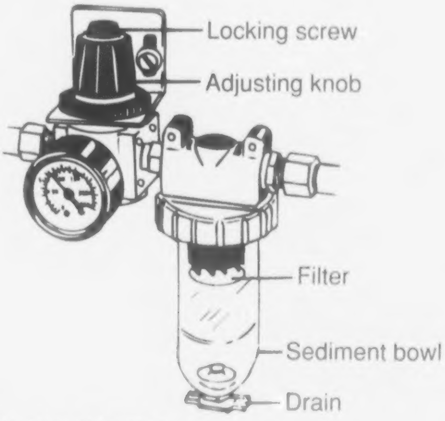
Guidelines for using compressed air with a PAC system

a. When compressed air is used with a PAC system, the air must be clean, dry, and oil-free. This will increase the life of consumables.

b. Many dual-flow PAC systems have air regulators attached to the machine, but in cases where air quality may be in question, it is wise to install an in-line filter between the air supply source and the regulator.

c. Regulator assemblies have an adjusting device to set p.s.i. and a filter with a sediment bowl that has a screw-type or pressure drain.

Figure 11



Courtesy of Smith Equipment.

d. Since the sediment bowl collects water, oil, and other matter, it must be drained or pressure purged each time the system is set up for cutting.

Objective 17

Factors affecting cutting speeds

a. Several factors affect cutting speeds for PAC, but the most important factors are:

- Power input
- Characteristics of gas flow, both cutting and secondary
- Nozzle design and orifice diameter
- Metal thickness

b. Other factors affecting cutting speeds are the condition of the equipment, the degree of wear on consumable parts, and operator skills.

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Note: The following chart shows suggested cutting speeds for mild steel. The medium range, 40 amps, is typical for PAC systems. Travel speeds for cutting aluminum are slower than for mild steel, and speeds for cutting stainless are even slower.

Material	Thickness (inches)	Thickness (mm)	Current (Amps)	Approximate Travel Speed (IPM)	Approximate Travel Speed (mm/min)
Mild Steel	28 GA	0.4	40	450	11400
	24 GA	0.6	40	350	8900
	18 GA	1.2	40	225	5700
	1/16	1.5	40	180	4600
	1/8	3	40	100	2500
	1/4	6	40	35	890
	3/8	9.5	40	15	380
	1/2	12	40	10	250

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c. Cutting speeds for mechanized PAC are considerably faster than speeds for hand cutting, and mechanized systems typically handle thicker metals.

Note: The following AWS chart displays typical conditions for mechanized cutting of carbon steel.

Thickness		Speed		Orifice Diam*		Current (dcsp), A	Power kW
in.	mm	in./min	mm/s	in.	mm		
1/4	6	200	86	1/8	3.2	275	55
1/2	13	100	42	1/8	3.2	275	55
1	25	50	21	5/32	4.0	425	85
2	51	25	11	3/16	4.8	550	110

*Plasma gas flow rates vary with orifice diameter and gas used from about 200 ft^3/h (94 L/min.) for a 1/8 in. (3.2 mm) orifice to about 300 ft^3/h (104 L/min.) for a 3/16 in. (4.8 mm) orifice. The gases used are usually compressed air, nitrogen with up to 10% hydrogen additions, or nitrogen with oxygen added downstream from the electrode (dual flow). The equipment manufacturer should be consulted for each application.

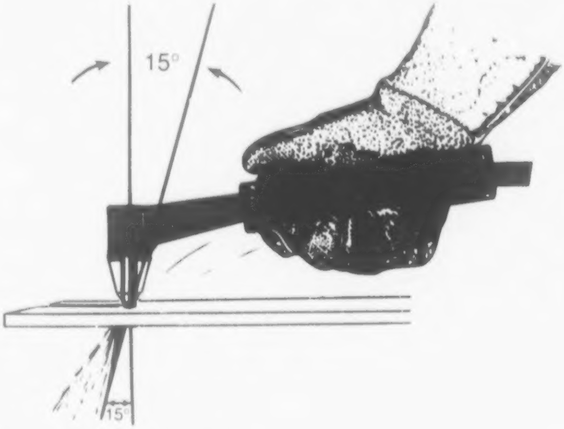
Adapted from American Welding Society, 1991, *Welding Handbook* Vol. 2, *Welding Processes*, Table 15.3.

Objective 18

Techniques for contact and stand-off cutting

a. For normal contact cutting, hold the torch with the arc directed at a slight angle in the same direction of travel.

Figure 12



Courtesy of Smith Equipment.

b. For stand-off cutting, change to the appropriate shield cup or stand-off device, and direct the arc at a 90° angle straight down at the workpiece.

Objective 19

Techniques for cutting expanded metal

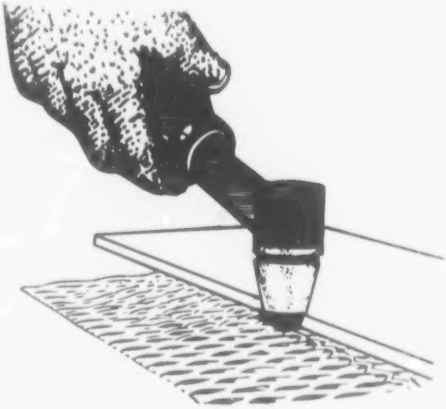
a. With some PAC systems, cutting expanded metal can be a problem because the arc has to be frequently restarted because of the open spaces that will not maintain electrical continuity.

b. To eliminate the problem with restarting the arc, place a thin piece of metal on top of the expanded metal, a straightedge is ideal.

c. Be sure the metal or straightedge is clamped in place so it will not have to be handled during the cutting process.

d. Drag the cutting nozzle along the metal guide, and there should be no problem with having to restart the arc.

Figure 13



Courtesy of Smith Equipment.

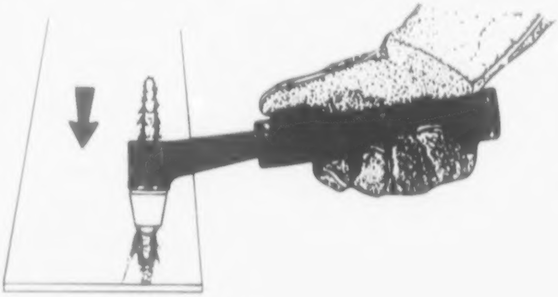
Objective 20

Techniques for gouging metal

a. Turn the power off, install the recommended electrode, and install a gouging nozzle on the torch so you will have a wider arc.

b. Start the arc by briefly dragging the torch across the metal surface, and immediately angle the torch at a gouging angle and push it across the surface.

Figure 14



Courtesy of Smith Equipment.

c. To make a shallow gouge, lessen the torch angle; to make a deeper gouge, increase the torch angle.

d. Do not attempt to remove too much metal in a single pass; repeat gouging if more metal needs to be removed.

> **Caution:** Metal gouging increases wear on consumables, and steep gouging angles could cause heat and slag to blow back into the nozzle and damage it.

e. When preparing a crack for repair or removing an inferior weld, make a wider gouge by weaving the torch.

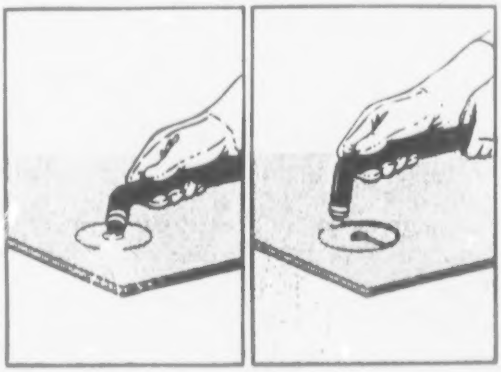
Objective 21

Techniques for piercing and beveling

a. Spray the shield cup with or dip the cup in antispatter compound to help minimize spatter and scale that adheres to the cup.

b. Start at a point slightly removed from the cut line and angle the torch slightly to blow particles away from the torch rather than back into the torch.

Figure 15



Courtesy of Thermal Dynamics/Division of Thermadyne

c. Move from the point that was pierced to the cutting line and finish the cut, and then clean any spatter or scale from the shield cup.

d. To bevel with a PAC system, angle the torch to the desired bevel angle, maintain a slight angle opposite the direction of travel, and make the cut.

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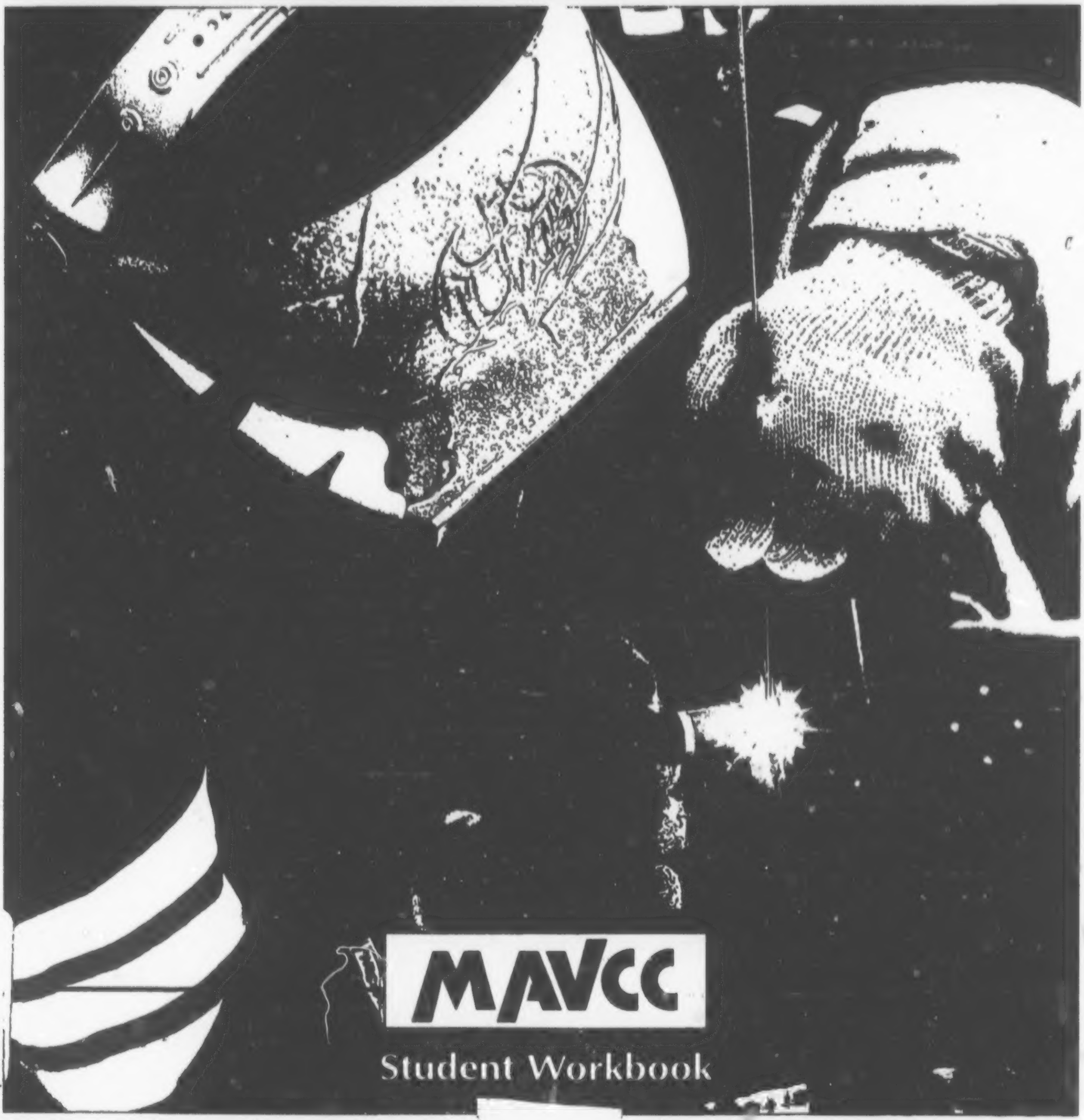
Objective 22

Common cutting problems and their probable causes

Problem	Probable Cause
Insufficient penetration	Cutting speed too fast Torch tilted too much Metal too thick Worn or damaged torch parts
Main arc extinguishes	Cutting speed too slow Stand-off too high
Dross formation	Improper cutting speed Worn or damaged torch parts

Gas Tungsten Arc Welding and Plasma Arc Cutting

SECOND EDITION



MAVCC

Student Workbook

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Gas Tungsten Arc Welding and Plasma Arc Cutting

Second Edition

Student Workbook

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Objective 16

Assignment Sheet 1—Solve Problems Concerning GTAW Safety

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Problems were recognized	______
• Solutions are accurate	______

Basic Skills

Reading Writing Critical Thinking Employability

Directions

Read the following statements carefully. Write a brief statement recommending a specific solution if a safety violation is presented.

1. A fellow student is preparing to start a GTAW job in an area where there is obviously some water on the floor. Is there a problem? __________

   Solution: ______________________________

2. A fellow student has left GTAW cables wrapped around an argon cylinder. Is there a problem? __________

   Solution: ______________________________

3. A fellow student complains that she sees white spots in front of her eyes every time she stops welding. Is there a problem? __________

   Solution: ______________________________

4. A coworker is sanding a piece of aluminum to clean oxide from the surface and is wearing only safety glasses. Is there a problem? __________

   Solution: ______________________________

5. A fellow student complains that the fumes produced when welding at his workstation are very irritating. Is there a problem?__________________

   Solution: ____

   ____

Objective 25

Job Sheet 1—Set Up a Flow Meter Regulator for GTAW Shielding Gases

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Cylinder safety	______
• Regulator installation	______
• Flow meter adjusting valve operation	______
• Flow meter adjustment	______

Basic Skills

Reading Critical Thinking Technology

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- GTAW machine with accessories
- Argon or helium cylinder
- Flow meter regulator
- Adjustable wrench or 7/8" open-end wrench
- Safety glasses

Procedure

☐ 1. Check to see that gas cylinder is safely secured in an upright position.

☐ 2. Remove the cylinder cap.

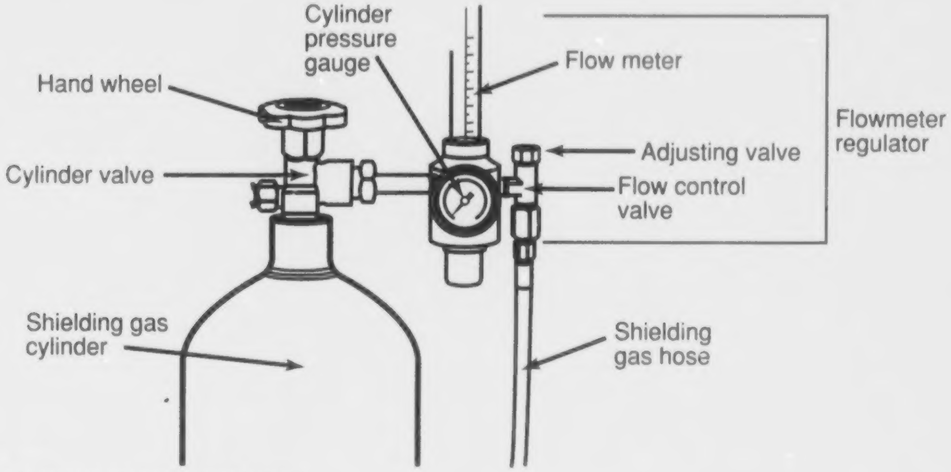
☐ 3. Crack the cylinder valve slightly to clear the cylinder valve fitting.

☐ 4. Attach the flow meter regulator to the cylinder valve so that it is vertical.

☐ 5. Tighten regulator fitting nut with wrench, but do not over tighten.

☐ 6. Check to make sure that flow meter adjusting valve is shut off, and if it isn't, turn it clockwise until it is tight.

Figure 1


Cylinder pressure gauge
Hand wheel
Flow meter
Flowmeter regulator
Adjusting valve
Cylinder valve
Flow control valve
Shielding gas cylinder
Shielding gas hose

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☐ 7. Stand to one side and open gas cylinder valve all the way so that it will back seat against the top of the valve.

☐ 8. Set up and turn on GTAW machine.

Note: Check with your instructor.

☐ 9. Turn flow meter adjusting screw counterclockwise until the ball starts to rise in the flow meter.

Note: If ball is not rising, depress foot pedal or check post flow timer.

☐ 10. Move the adjusting valve clockwise or counterclockwise to make adjustment to CFH desired.

Note: The very top of the ball is the reference point for measuring CFH.

☐ 11. Have your instructor check your work.

☐ 12. Shut down and secure equipment.

☐ 13. Return tools to proper storage.

Evaluator's Comments: ____________________

____

____

Objective 26

Job Sheet 2—Set Up and Shut Down GTAW Equipment for Welding Mild or Stainless Steel

Name ____________________ Attempt Number ________

Date ____________________ Overall Rating ________

Evaluation Criteria	Rating
• Set up and machine settings	______
• Flow meter setting	______
• Coolant system check	______
• Tungsten electrode preparation	______
• Shut down properly	______

Basic Skills

Reading

Critical Thinking

Technology

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- GTAW machine with accessories
- Personal safety clothing and equipment
- Tungsten electrode
- Shielding gas as selected by instructor
- Safety glasses

Procedure

☐ 1. Set up power supply.

☐ 2. Set current range selector according to metal thickness.

☐ 3. Set polarity switch to DCEN.

☐ 4. Set weld control switch to GTAW.

☐ 5. Set high frequency switch to "START ONLY" position.

☐ 6. Set control for soft start.

☐ 7. Set remote control switch for contactor or amperage control to either remote or panel depending on machine accessories.

☐ 8. Set post flow timer according to electrode size.

☐ 9. Turn on cylinder valve and adjust flow meter regulator to rate of flow recommended for electrode.

☐ 10. Check for proper and complete circulation in the cooling system and verify that there are no leaks.

☐ 11. Select correct size collet and gas nozzle according to electrode size.

☐ 12. Prepare the tungsten electrode with a pointed tip. (See Job Sheet 4.)

☐ 13. Adjust the electrode extension to no more than 1/8".

☐ 14. Connect ground clamp to base metal.

☐ 15. Switch machine on.

☐ 16. Have your instructor check your set-up procedure.

☐ 17. Prepare for shut-down procedure.

☐ 18. Close gas cylinder valve.

☐ 19. Depress foot control to bleed gas line.

☐ 20. Shut off flow meter regulator.

☐ 21. Turn off cooling system.

☐ 22. Turn off power switch.

☐ 23. Remove electrode from torch and return to proper storage.

☐ 24. Remove collet and gas nozzle and return to proper storage.

☐ 25. Disconnect ground clamp.

☐ 26. Roll cables up neatly and clean up workstation.

☐ 27. Return tools and materials to proper storage.

☐ 28. Have your instructor check your shutdown procedure.

Evaluator's Comments: ______________________________

____

____

Objective 27

Job Sheet 3—Prepare Mild or Stainless Steel for GTAW

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Scale removal	______
• Edge preparation	______
• Wire or stainless brush use	______
• Washed, dried, and wiped mild and stainless steel properly	______

Basic Skills

Reading

Critical Thinking

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Mild or stainless steel as selected by instructor
- Wire and stainless steel brushes
  Note: Use stainless steel brush on stainless steel only.
- Sander/grinder
- Pliers and clamps
- Combination cleaner-deoxidizer
- Clean shop rags
- Safety clothing, safety glasses, and face shield

Procedure

☐ 1. Secure workpiece with clamps or vise.

☐ 2. Remove all scale, rust, dirt, and paint from all surfaces with a sander/grinder.

☐ 3. Grind edges of joints for specified edge preparation.

☐ 4. Wire brush or stainless steel brush as required.

☐ 5. Wash stainless steel with a solution of cleaner-deoxidizer and allow to air dry before welding.

☐ 6. Wipe mild steel down with a clean, dry shop rag and store in a dry place prior to welding.

☐ 7. Have your instructor check your work.

Evaluator's Comments: ________________________________

____

____

Objective 28

Job Sheet 4—Prepare a Tungsten Electrode for Welding Mild or Stainless Steel

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation Criteria	Rating
• Tungsten placement on wheel	______
• Tungsten shaping with grain	______
• Quality taper and point	______

Basic Skills

Reading Mathematics Critical Thinking

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Pedestal grinder
- Minimum 120-grit grinding wheel
- Electrode as selected by instructor
- Safety clothing, safety glasses, and face shield

Procedure

☐ 1. Determine diameter of electrode.

☐ 2. Measure or estimate a distance equal to two or two and a half times the diameter of the electrode to serve as a guide for length of point.

☐ 3. Turn grinder on and allow wheel to reach full rpm.

☐ 4. Hold the electrode firmly and place it gently against the grinder so that direction of grinding will run in the direction of the length of the electrode and not crosswise to the length.

> **Caution:** Manipulate the electrode with your fingers and don't allow the end of the electrode to jab the palm of your hand.

☐ 5. Turn the tungsten slowly as you grind to give a uniform bevel to the grind and keep the point of the electrode at the center.

☐ 6. Grind the electrode to a needle point for a job that calls for low amperage starting on thin gauge metal.

☐ 7. Have your instructor check your work.

☐ 8. Dull the point slightly on the grinding wheel for a job that calls for higher amperage welding on thicker gauge metal.

☐ 9. Have your instructor check your work.

☐ 10. If the electrode appears to be contaminated, nick a spot near the end on the grinding wheel, break the tip off with pliers, and grind the electrode again.

☐ 11. Turn grinder off.

☐ 12. Have your instructor check your work.

☐ 13. Secure equipment and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

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Objective 29

Job Sheet 5—Strike and Maintain an Arc to Make Stringer Beads on Mild or Stainless Steel Without Filler Metal in the Flat Position

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Equipment setup and safety	______
• Electrode extension	______
• Shielding gas adjustment	______
• Stringer bead quality	______

Basic Skills

Reading

Critical Thinking

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

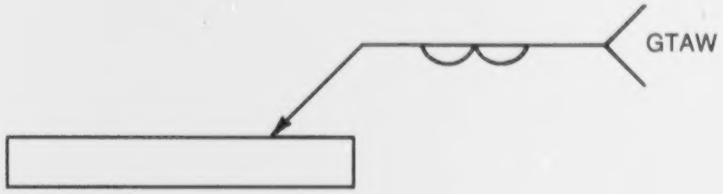
Tools, equipment, and materials

- GTAW machine with accessories
- Tungsten electrode to specifications
- Shielding gas to specifications
- Mild or stainless steel as selected by instructor
- Wire brush and pliers
- Safety clothing and safety glasses

Specifications

1. Joint design and weld symbol:

Figure 1



2. Filler metal: N/A
3. Tungsten: Per instructor
4. Shielding gas: Ar or He

5. Electrical: DCEN high frequency set on start only

6. Position: Flat

7. Direction of welding: N/A

8. Technique: Steady forward motion

9. Cleaning: N/A

10. Testing: Visual

Procedure

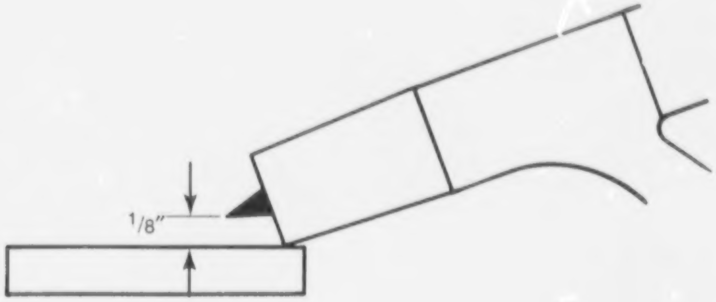
☐ 1. Set up equipment as previously outlined.

☐ 2. Double check electrode extension and shielding gas flow rate.

☐ 3. Position plate in accordance with specifications, and hold torch with right hand, if right handed, or opposite if left handed.

☐ 4. Move torch so that nozzle rests on base metal with electrode about 1/8″ off base metal.

Figure 2



☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

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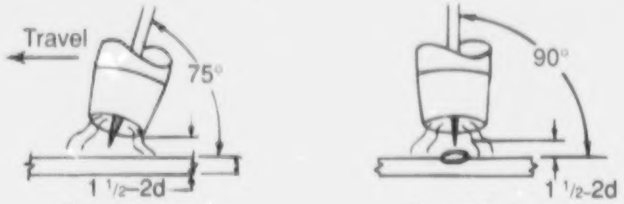
☐ 6. Correct electrode angle the moment the arc is established.

Figure 3



Side View Front View

Courtesy of Lincoln Electric Company.

☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move electrode slowly in the direction of travel, maintaining correct arc length, bead width, and electrode angle. Hold as close an arc length as possible.

Note: The bead should penetrate the plate, but should not go through the plate causing burn through.

☐ 9. Stop just as you reach the end of the plate and start letting off on the foot control.

☐ 10. Let off on foot control and keep torch in place for a few seconds after end of the weld.

☐ 11. Place torch in a secure, safe place.

☐ 12. Secure plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 13. Have your instructor check your work.

☐ 14. Continue making passes as directed by your instructor.

☐ 15. Visually inspect each pass and have your instructor check your work.

☐ 16. Shut down equipment as previously outlined.

☐ 17. Check in tools and materials and clean area.

Evaluator's Comments: ______________________________

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Objective 30

Job Sheet 6—Strike and Maintain an Arc to Make Stringer Beads on Mild or Stainless Steel With Filler Metal in the Flat Position

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Equipment setup and safety	______
• Electrode extension	______
• Shielding gas adjustment	______
• Filler metal application	______
• Stringer bead quality	______

Basic Skills

Reading

Critical Thinking

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

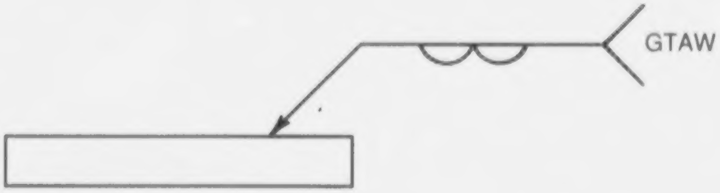
Tools, equipment, and materials

- GTAW machine with accessories
- Tungsten electrode to specifications
- Shielding gas to specifications
- Filler metal as selected by instructor
- Mild or stainless steel as selected by instructor
- Wire brush and pliers (use stainless steel brush on stainless steel)
- Safety clothing and safety glasses

Specifications

1. Joint design and weld symbol:

Figure 1



2. Filler metal: Mild or stainless steel per instructor

3. Tungsten: Per instructor

4. Shielding gas: Ar or He
5. Electrical: DCEN high frequency set on start only
6. Position: Flat
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: N/A
10. Testing: Visual

Procedure

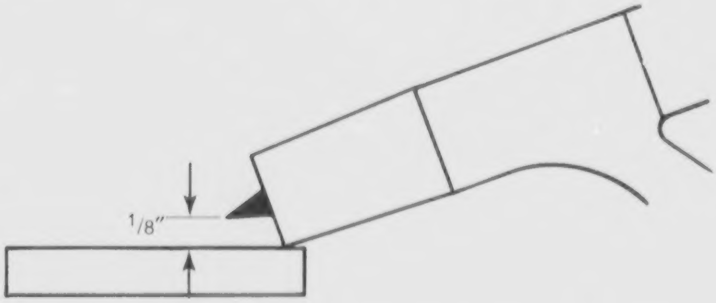
☐ 1. Set up equipment as previously outlined.

☐ 2. Double check electrode extension and shielding gas flow rate.

☐ 3. Position plate in accordance with specifications, and hold torch with right hand, if right handed, or opposite if left handed.

☐ 4. Move torch so that nozzle rests on base metal with electrode about 1/8" off base metal.

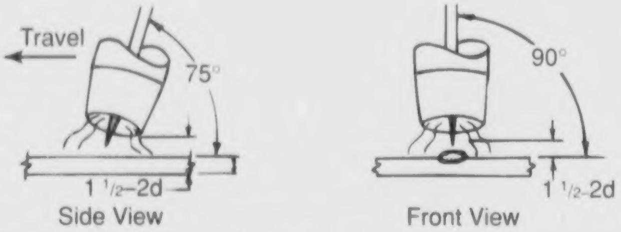
Figure 2



☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

☐ 6. Correct electrode angle the moment the arc is established.

Figure 3

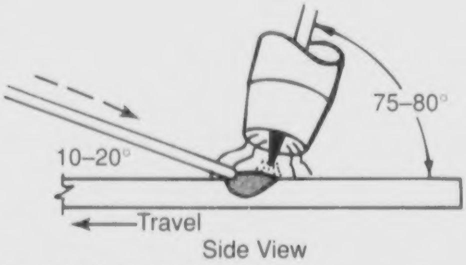


Courtesy of Lincoln Electric Company.

☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.

Figure 4



Courtesy of Lincoln Electric Company.

☐ 9. Withdraw filler rod about 1/2″ from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 14. Have your instructor check your work.

☐ 15. Continue making passes as directed by your instructor.

☐ 16. Visually inspect each pass and have your instructor check your work.

☐ 17. Shut down equipment as previously outlined.

☐ 18. Check in tools and materials and clean area.

Evaluator's Comments: ______________________________

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Objective 31

Job Sheet 7—Weld to Specifications a Fillet Weld Lap Joint on Mild or Stainless Steel in the Flat Position

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Equipment setup and safety	______
• Electrode extension	______
• Shielding gas adjustment	______
• Filler metal application	______
• Weld quality	______

Basic Skills

Reading Critical Thinking Technology

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

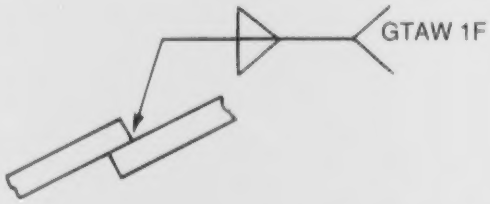
- GTAW machine with accessories
- Tungsten electrode to specifications
- Shielding gas to specifications
- Filler metal as selected by instructor
- Mild or stainless steel as selected by instructor
- Wire brush and pliers (use stainless steel brush on stainless steel)

- Safety clothing and safety glasses

Specifications

1. Joint design and weld symbol:

Figure 1



2. Filler metal: Mild or stainless steel per instructor

3. Tungsten: Per instructor

4. Shielding gas: Ar or He
5. Electrical: DCEN high frequency set on start only
6. Position: 1F
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: N/A
10. Testing: Visual

Procedure

☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.

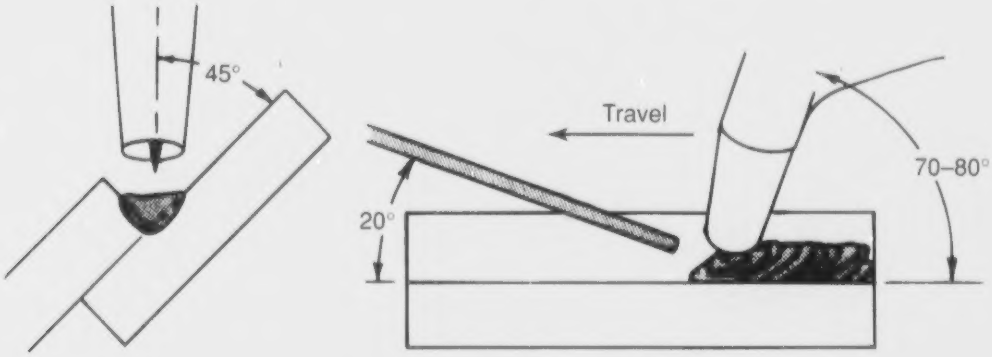
☐ 2. Tack weld plates on both ends for specified joint.

☐ 3. Position plate in accordance with specifications.

☐ 4. Lower welding hood and depress foot control until the arc jumps the gap and is established.

☐ 5. Correct electrode angle the moment the arc is established.

Figure 2



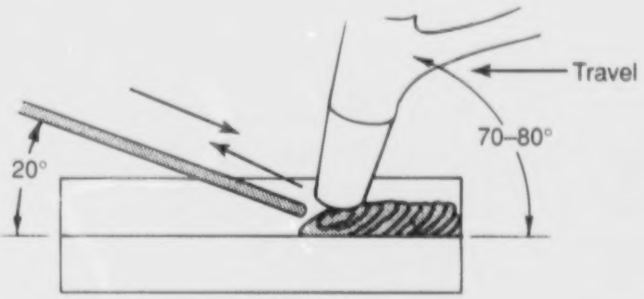
Front View

Side View

☐ 6. Preheat the starting point until a small molten puddle is formed.

☐ 7. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.

Figure 3



Side View

☐ 8. Withdraw filler rod about 1/2" from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 9. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 10. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

☐ 11. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 12. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 13. Have your instructor check your work.

☐ 14. Continue making passes as directed by your instructor.

☐ 15. Visually inspect each pass and have your instructor check your work.

☐ 16. Repeat procedure for other side of joint, if required and have your instructor check your work.

☐ 17. Shut down equipment as previously outlined.

☐ 18. Check in tools and materials and clean area.

Evaluator's Comments: ______________________________

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Objective 32

Job Sheet 8—Weld to Specifications a Fillet Weld T-Joint on Mild or Stainless Steel in the Flat Position

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Equipment setup and safety	______
• Electrode extension	______
• Shielding gas adjustment	______
• Filler metal application	______
• Weld quality	______

Basic Skills

Reading Critical Thinking Technology

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

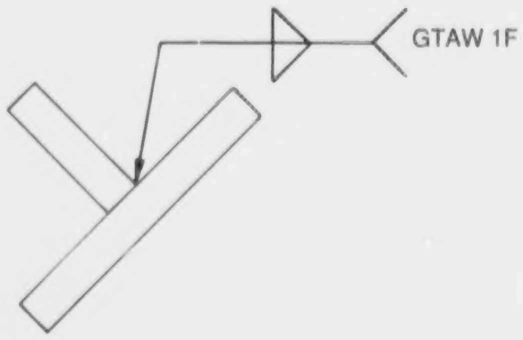
Tools, equipment, and materials

- GTAW machine with accessories
- Tungsten electrode to specifications
- Shielding gas to specifications
- Filler metal as selected by instructor
- Mild or stainless steel as selected by instructor
- Wire brush and pliers (use stainless steel brush on stainless steel)
- Safety clothing and safety glasses

Specifications

1. Joint design and weld symbol:

Figure 1



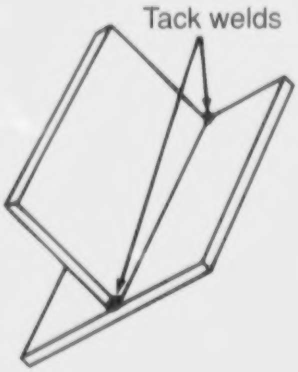
2. Filler metal: Mild or stainless steel per instructor
3. Tungsten: Per instructor
4. Shielding gas: Ar or He
5. Electrical: DCEN high frequency set on start only
6. Position: 1F
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: N/A
10. Testing: Visual

Procedure

☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.

☐ 2. Tack weld plates on both ends for specified joint.

Figure 2



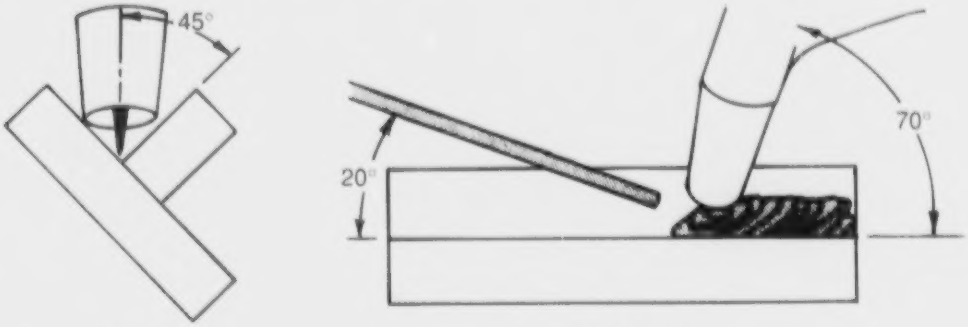
☐ 3. Position plate in accordance with specifications.

☐ 4. Move torch so that nozzle rests on base metal with electrode about 1/8" off base metal.

☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

☐ 6. Correct electrode angle the moment the arc is established.

Figure 3

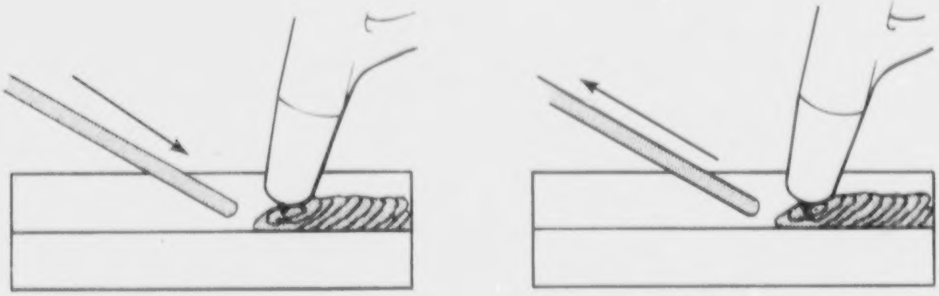


Front View Side View

☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.

Figure 4



Side View Side View

☐ 9. Withdraw filler rod about 1/2″ from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

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☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 14. Have your instructor check your work.

☐ 15. Continue making passes as directed by your instructor.

☐ 16. Visually inspect each pass and have your instructor check your work.

☐ 17. Repeat procedure for other side of joint, if required and have your instructor check your work.

☐ 18. Shut down equipment as previously outlined.

☐ 19. Check in tools and materials and clean area.

Evaluator's Comments:

Objective 33

Job Sheet 9—Weld to Specifications an Open-Root Square-Grove Butt Joint on Mild or Stainless Steel in the Flat Position

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
• Equipment setup and safety	______
• Use of gap wire and supports	______
• Electrode extension	______
• Shielding gas adjustment	______
• Filler metal application	______
• Grinding root preparation	______
• Weld quality	______

Basic Skills

Reading Critical Thinking Technology

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

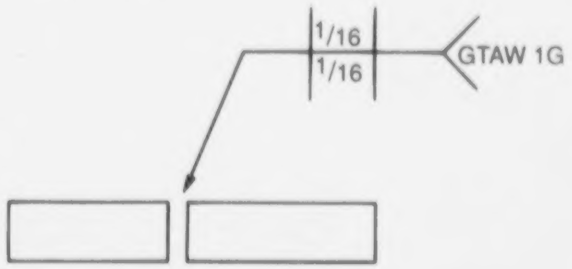
Tools, equipment, and materials

- GTAW machine with accessories
- Tungsten electrode to specifications
- Shielding gas to specifications
- Filler metal as selected by instructor
- Mild or stainless steel as selected by instructor
- Wire brush, pliers, and portable grinder
  Note: Use stainless steel brush on stainless steel.
- $^1/_{16}$" gap wire with support plates
- Safety clothing and safety glasses

Specifications

1. Joint design and weld symbol:

Figure 1



2. Filler metal: Mild or stainless steel per instructor
3. Tungsten: Per instructor
4. Shielding gas: Ar or He
5. Electrical: DCEN high frequency set on start only
6. Position: 1G
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: N/A
10. Testing: Visual

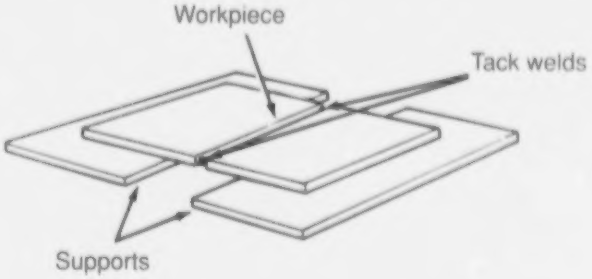
Procedure

☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.

☐ 2. Use a 1/16" gap wire and place the plates into position and tack weld both ends.

☐ 3. Position plate in accordance with specifications.

Figure 2

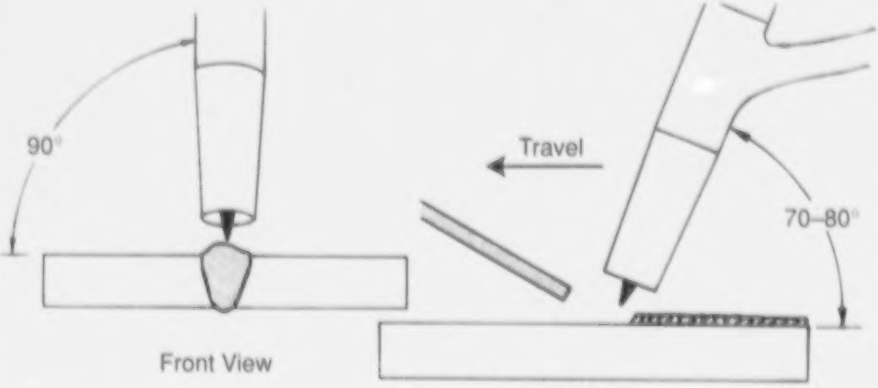


☐ 4. Move torch so that nozzle rests on base metal with electrode about 1/8" off base metal.

☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

☐ 6. Correct electrode angle the moment the arc is established.

Figure 3



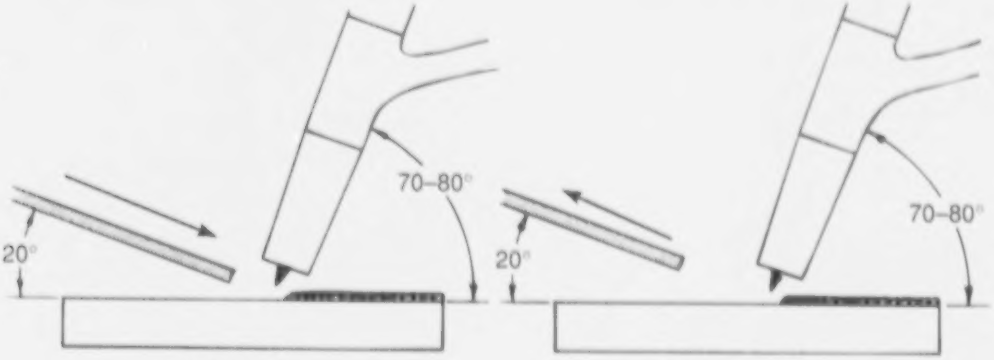
Front View

Side View

☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.

Figure 4



Side View

Side View

☐ 9. Withdraw filler rod about 1/2" from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 14. Have your instructor check your work.

☐ 15. Continue making passes as directed by your instructor.

☐ 16. Visually inspect each pass and have your instructor check your work.

☐ 17. Grind out root side of joint prior to welding other side.

☐ 18. Weld other side of joint, if directed by your instructor.

☐ 19. Have your instructor check your work.

☐ 20. Shut down equipment as previously outlined.

☐ 21. Check in tools and materials and clean area.

Evaluator's Comments: ______________________________

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Objective 34

Job Sheet 10—Weld to Specifications a Fillet Weld Lap Joint on Mild or Stainless Steel in the Horizontal Position

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Equipment setup and safety	______
• Electrode extension	______
• Shielding gas adjustment	______
• Filler metal application	______
• Weld quality	______

Basic Skills

Reading Critical Thinking Technology

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

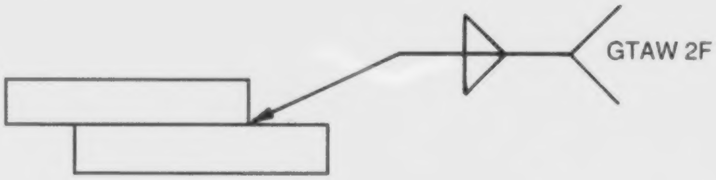
Tools, equipment, and materials

- GTAW machine with accessories
- Tungsten electrode to specifications
- Shielding gas to specifications
- Filler metal as selected by instructor
- Mild or stainless steel as selected by instructor
- Wire brush (use stainless steel brush on stainless steel)
- Safety clothing and safety glasses

Specifications

1. Joint design and weld symbol:

Figure 1



2. Filler metal: Mild or stainless steel per instructor

3. Tungsten: Per instructor

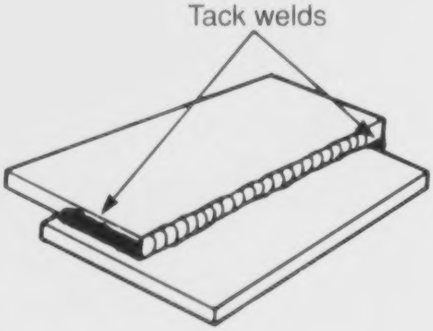
4. Shielding gas: Ar or He
5. Electrical: DCEN high frequency set on start only
6. Position: 2F
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: N/A
10. Testing: Visual

Procedure

☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.

☐ 2. Place plates in correct joint position and tack weld both ends.

Figure 2



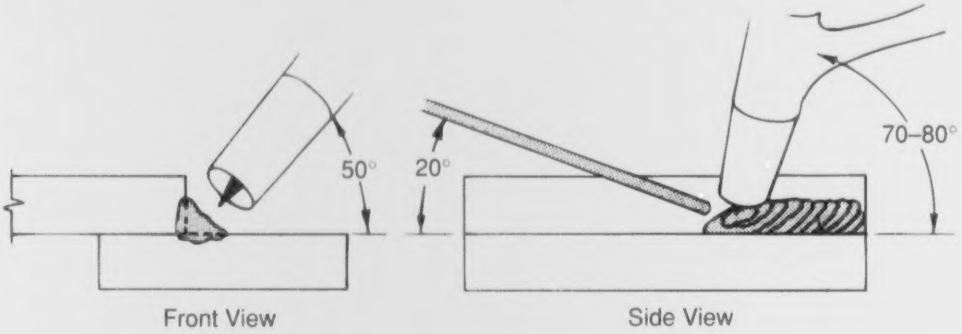
☐ 3. Position plate in accordance with specifications.

☐ 4. Move torch so that nozzle rests on base metal with electrode about $^{1}/_{8}$″ off base metal.

☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

☐ 6. Correct electrode angle the moment the arc is established.

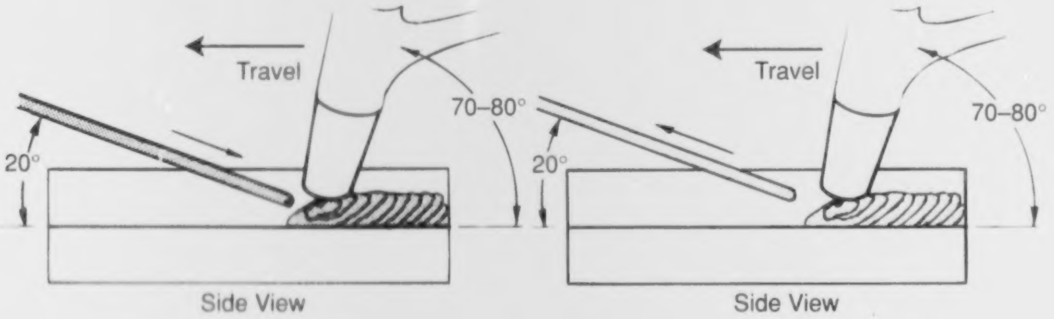
Figure 3



☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.

Figure 4



☐ 9. Withdraw filler rod about 1/2" from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 14. Have your instructor check your work.

☐ 15. Continue making passes as directed by your instructor.

☐ 16. Visually inspect each pass and have your instructor check your work.

☐ 17. Repeat procedure for other side of joint, if required and have your instructor check your work.

☐ 18. Shut down equipment as previously outlined.

☐ 19. Check in tools and materials and clean area.

Evaluator's Comments: ______________________________

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Objective 35

Job Sheet 11—Weld to Specifications a Fillet Weld T-Joint on Mild or Stainless Steel in the Horizontal Position

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
• Equipment setup and safety	______
• Electrode extension	______
• Shielding gas adjustment	______
• Filler metal application	______
• Weld quality	______

Basic Skills

Reading Critical Thinking Technology

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

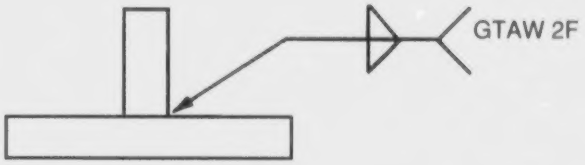
Tools, equipment, and materials

- GTAW machine with accessories
- Tungsten electrode to specifications
- Shielding gas to specifications
- Filler metal as selected by instructor
- Mild or stainless steel as selected by instructor
- Wire brush and pliers (use stainless steel brush on stainless steel)
- Safety clothing and safety glasses

Specifications

1. Joint design and weld symbol:

Figure 1



2. Filler metal: Mild or stainless steel per instructor

3. Tungsten: Per instructor

4. Shielding gas: Ar or He

5. Electrical: DCEN high frequency set on start only

6. Position: 2F

7. Direction of welding: N/A

8. Technique: Steady forward motion

9. Cleaning: N/A

10. Testing: Visual

Procedure

☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.

☐ 2. Place plates in correct joint position and tack weld both ends.

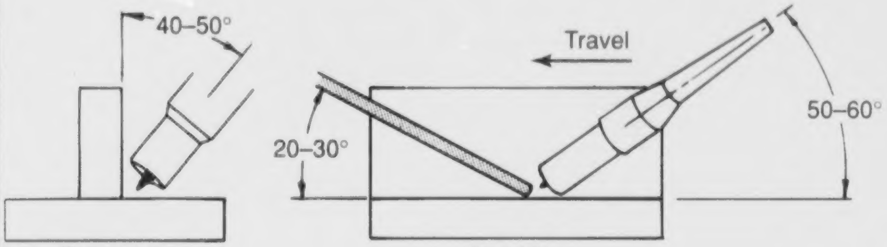
☐ 3. Position plate in accordance with specifications.

☐ 4. Move torch so that nozzle rests on base metal with electrode about 1/8" off base metal.

☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

☐ 6. Correct electrode angle the moment the arc is established.

Figure 2



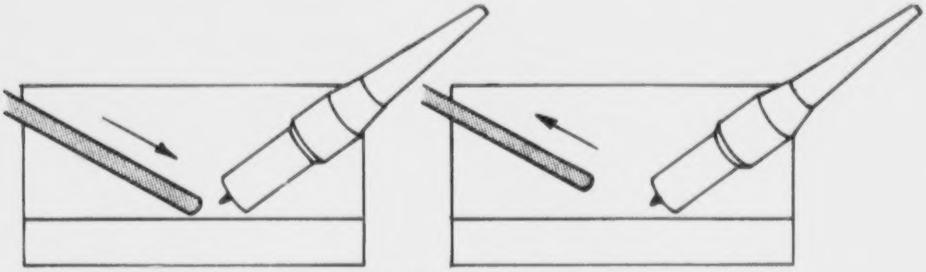
Front View

Side View

☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.

Figure 3



Side View

☐ 9. Withdraw filler rod about 1/2" from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 14. Have your instructor check your work.

☐ 15. Continue making passes as directed by your instructor.

☐ 16. Visually inspect each pass and have your instructor check your work.

☐ 17. Repeat procedure for other side of joint, if required and have your instructor check your work.

☐ 18. Shut down equipment as previously outlined.

☐ 19. Check in tools and materials and clean area.

Evaluator's Comments:

Objective 36

Job Sheet 12—Weld to Specifications a Fillet Weld Lap Joint on Mild or Stainless Steel in the Vertical Position

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Equipment setup and safety	______
• Electrode extension	______
• Shielding gas adjustment	______
• Filler metal application	______
• Weld quality	______

Basic Skills

Reading Critical Thinking Technology

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

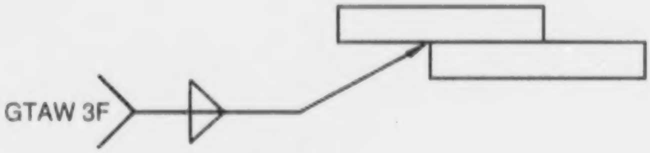
Tools, equipment, and materials

- GTAW machine with accessories
- Tungsten electrode to specifications
- Shielding gas to specifications
- Filler metal as selected by instructor
- Mild or stainless steel as selected by instructor
- Wire brush and pliers (use stainless steel brush on stainless steel)
- Safety clothing and safety glasses

Specifications

1. Joint design and weld symbol:

Figure 1



Top View

2. Filler metal: Mild or stainless steel per instructor

3. Tungsten: Per instructor

4. Shielding gas: Ar or He
5. Electrical: DCEN high frequency set on start only
6. Position: 3F
7. Direction of welding: Vertical up
8. Technique: Steady forward motion
9. Cleaning: N/A
10. Testing: Visual

Procedure

☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.

☐ 2. Place plates in correct joint position and tack weld both ends.

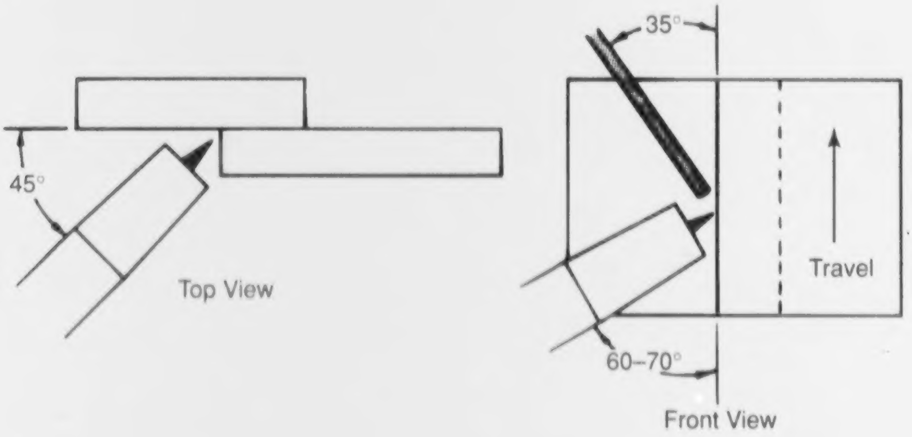
☐ 3. Position plate in accordance with specifications.

☐ 4. Move torch so that nozzle rests on base metal with electrode about 1/8" off base metal.

☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

☐ 6. Correct electrode angle the moment the arc is established.

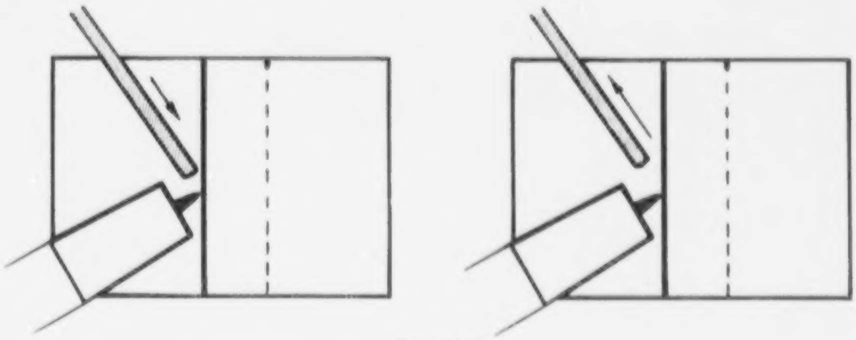
Figure 2



☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.

Figure 3



Front View

☐ 9. Withdraw filler rod about 1/2" from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 14. Have your instructor check your work.

☐ 15. Continue making passes as directed by your instructor.

☐ 16. Visually inspect each pass and have your instructor check your work.

☐ 17. Repeat procedure for other side of joint, if required and have your instructor check your work.

☐ 18. Shut down equipment as previously outlined.

☐ 19. Check in tools and materials and clean area.

Evaluator's Comments: ______________________________

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Objective 37

Job Sheet 13—Weld to Specifications a Fillet Weld T-Joint on Mild or Stainless Steel in the Vertical Position

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Equipment setup and safety	______
• Electrode extension	______
• Shielding gas adjustment	______
• Filler metal application	______
• Weld quality	______

Basic Skills

Reading Critical Thinking Technology

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

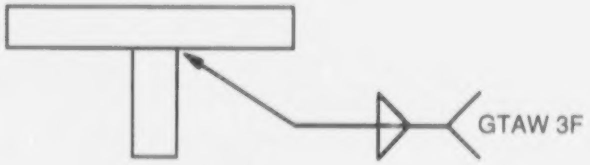
Tools, equipment, and materials

- GTAW machine with accessories
- Tungsten electrode to specifications
- Shielding gas to specifications
- Filler metal as selected by instructor
- Mild or stainless steel as selected by instructor
- Wire brush and pliers (use stainless steel brush on stainless steel)
- Safety clothing and safety glasses

Specifications

1. Joint design and weld symbol:

Figure 1



Top View

2. Filler metal: Mild or stainless steel per instructor

3. Tungsten: Per instructor

4. Shielding gas: Ar or He
5. Electrical: DCEN high frequency set on start only
6. Position: 3F
7. Direction of welding: Vertical up
8. Technique: Steady forward motion
9. Cleaning: N/A
10. Testing: Visual

Procedure

☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.

☐ 2. Place plates in correct joint position and tack weld both ends.

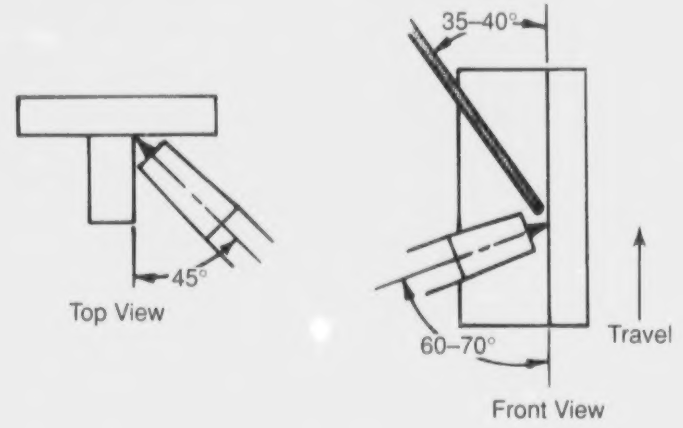
☐ 3. Position plate in accordance with specifications.

☐ 4. Move torch so that nozzle rests on base metal with electrode about $^1/_8$" off base metal.

☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

☐ 6. Correct electrode angle the moment the arc is established.

Figure 2



☐ 7. Preheat the starting point until a small molten puddle is formed.

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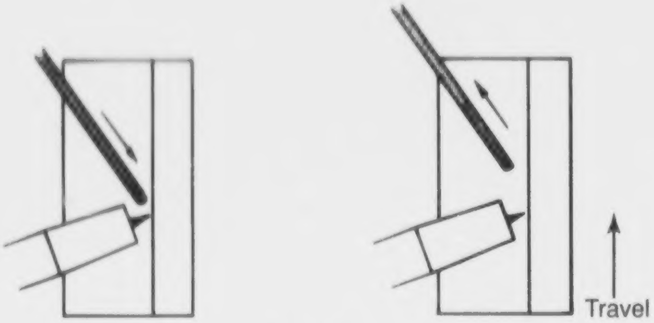
☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.

Figure 3



Front View

☐ 9. Withdraw filler rod about 1/2" from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 14. Have your instructor check your work.

☐ 15. Continue making passes as directed by your instructor.

☐ 16. Visually inspect each pass and have your instructor check your work.

☐ 17. Repeat procedure for other side of joint, if required and have your instructor check your work.

☐ 18. Shut down equipment as previously outlined.

☐ 19. Check in tools and materials and clean area.

Evaluator's Comments: ______________________________

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Objective 38

Job Sheet 14—Weld to Specifications an Open-Root Square-Groove Butt Joint on Mild or Stainless Steel in the Vertical Position

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Equipment setup and safety	______
• Use of gap wire and supports	______
• Electrode extension	______
• Shielding gas adjustment	______
• Filler metal application	______
• Grinding root preparation	______
• Weld quality	______

Basic Skills

Reading Critical Thinking Technology

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

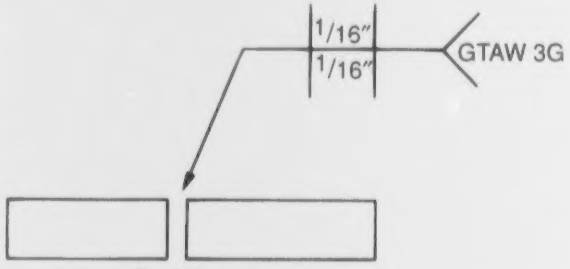
Tools, equipment, and materials

- GTAW machine with accessories
- Tungsten electrode to specifications
- Shielding gas to specifications
- Filler metal as selected by instructor
- Mild or stainless steel as selected by instructor
- Wire brush, pliers, and portable grinder
  Note: Use stainless steel brush on stainless steel.
- Safety clothing and safety glasses

Specifications

1. Joint design and weld symbol:

Figure 1



2. Filler metal: Mild or stainless steel per instructor
3. Tungsten: Per instructor
4. Shielding gas: Ar or He
5. Electrical: DCEN high frequency set on start only
6. Position: 3G
7. Direction of welding: Vertical up
8. Technique: Steady forward motion
9. Cleaning: N/A
10. Testing: Visual

Procedure

☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.

☐ 2. Use a 1/16″ gap wire and place the plates into position and tack weld both ends.

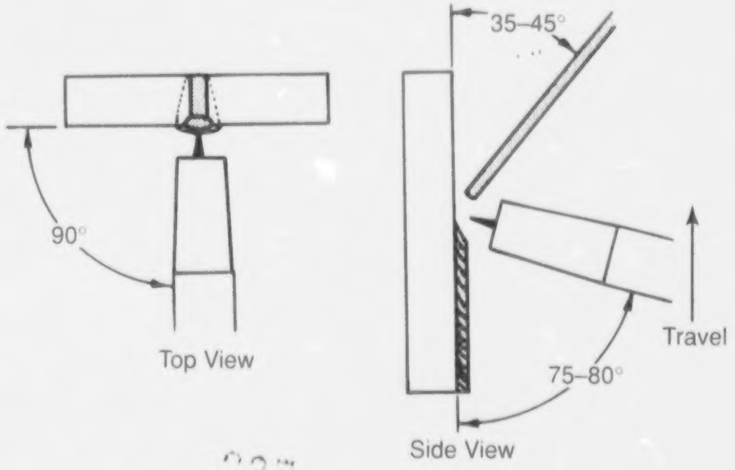
☐ 3. Position plate in accordance with specifications.

☐ 4. Move torch so that nozzle rests on base metal with electrode about 1/8″ off base metal.

☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

☐ 6. Correct electrode angle the moment the arc is established.

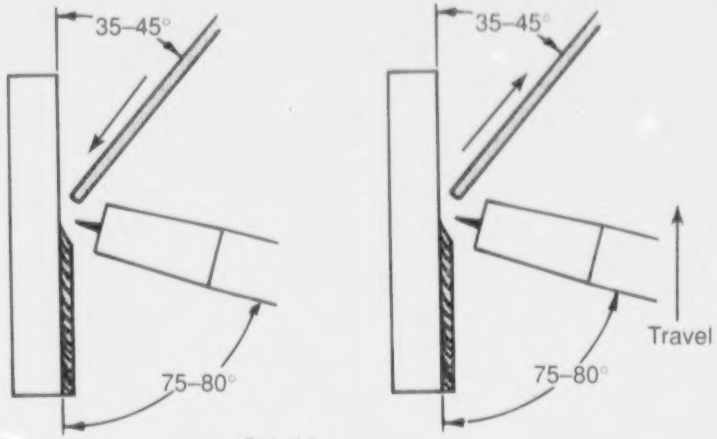
Figure 2



☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.

Figure 3



Side View

☐ 9. Withdraw filler rod about 1/2" from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 14. Have your instructor check your work.

☐ 15. Continue making passes as directed by your instructor.

☐ 16. Visually inspect each pass and have your instructor check your work.

☐ 17. Grind out root side of joint prior to welding other side.

☐ 18. Weld other side of joint, if directed by your instructor.

☐ 19. Have your instructor check your work.

☐ 20. Shut down equipment as previously outlined.

☐ 21. Check in tools and materials and clean area.

Evaluator's Comments: ____________________

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Objective 39

Job Sheet 15—Weld to Specifications a Fillet Weld Lap Joint on Mild or Stainless Steel in the Overhead Position

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
• Equipment setup and safety	______
• Electrode extension	______
• Shielding gas adjustment	______
• Filler metal application	______
• Weld quality	______

Basic Skills

Reading Critical Thinking Technology

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

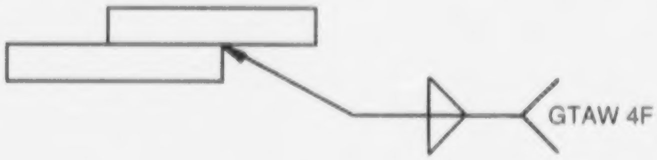
Tools, equipment, and materials

- GTAW machine with accessories
- Tungsten electrode to specifications
- Shielding gas to specifications
- Filler metal as selected by instructor
- Mild or stainless steel as selected by instructor
- Wire brush and pliers (use stainless steel brush on stainless steel)
- Safety clothing and safety glasses

Specifications

1. Joint design and weld symbol:

Figure 1



2. Filler metal: Mild or stainless steel per instructor

3. Tungsten: Per instructor

4. Shielding gas: Ar or He

5. Electrical: DCEN high frequency set on start only
6. Position: 4F
7. Direction of welding: Vertical up
8. Technique: Steady forward motion
9. Cleaning: N/A
10. Testing: Visual

Procedure

☐ 1. Set up equipment as previously outlined.

☐ 2. Check with your instructor about electrode extension and flow rate setting because overhead welding sometimes requires adjustment to flow rate and extension.

☐ 3. Place plates in correct joint position and tack weld both ends.

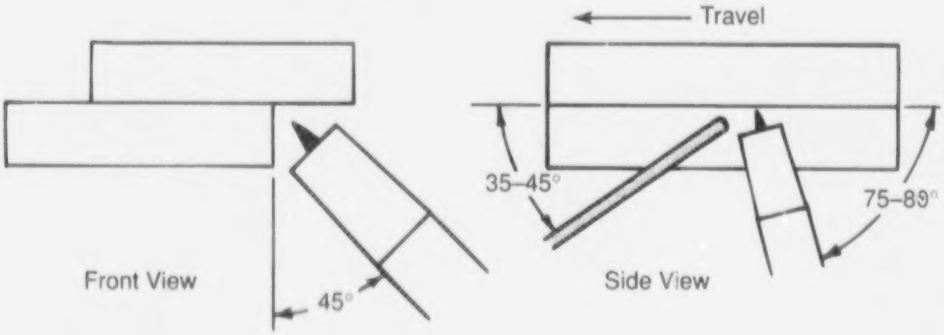
☐ 4. Position plate in accordance with specifications.

☐ 5. Move torch so that nozzle rests on base metal with electrode about $^1/_8$" off base metal.

☐ 6. Lower welding hood and depress foot control until the arc jumps the gap and is established.

☐ 7. Correct electrode angle the moment the arc is established.

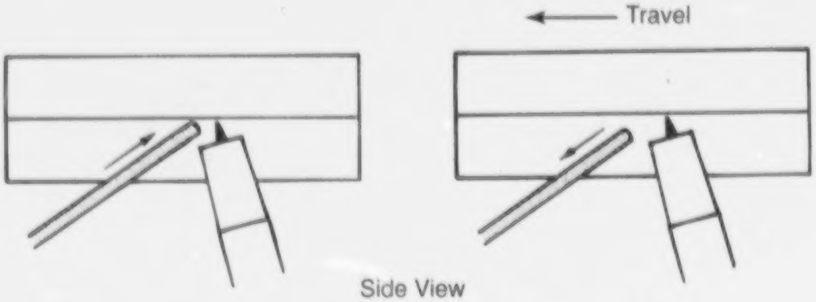
Figure 2



☐ 8. Preheat the starting point until a small molten puddle is formed.

☐ 9. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.

Figure 3



Side View

☐ 10. Withdraw filler rod about 1/2" from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 11. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 12. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

☐ 13. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 14. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 15. Have your instructor check your work.

☐ 16. Continue making passes as directed by your instructor.

☐ 17. Visually inspect each pass and have your instructor check your work.

☐ 18. Repeat procedure for other side of joint, if required and have your instructor check your work.

☐ 19. Shut down equipment as previously outlined.

☐ 20. Check in tools and materials and clean area.

Evaluator's Comments: ______________________________

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Objective 40

Job Sheet 16—Weld to Specifications a Fillet Weld T-Joint on Mild or Stainless Steel in the Overhead Position

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
• Equipment setup and safety	______
• Electrode extension	______
• Shielding gas adjustment	______
• Filler metal application	______
• Weld quality	______

Basic Skills

Reading Critical Thinking Technology

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

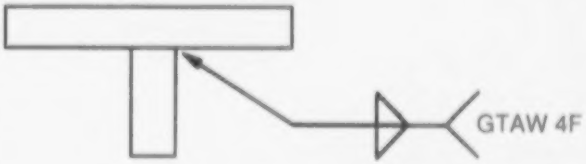
Tools, equipment, and materials

- GTAW machine with accessories
- Tungsten electrode to specifications
- Shielding gas to specifications
- Filler metal as selected by instructor
- Mild or stainless steel as selected by instructor
- Wire brush and pliers (use stainless steel brush on stainless steel)
- Safety clothing and safety glasses

Specifications

1. Joint design and weld symbol:

Figure 1



Top View

2. Filler metal: Mild or stainless steel per instructor

3. Tungsten: Per instructor

4. Shielding gas: Ar or He
5. Electrical: DCEN high frequency set on start only
6. Position: 4F
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: N/A
10. Testing: Visual

Procedure

☐ 1. Set up equipment as previously outlined.

☐ 2. Check with your instructor about electrode extension and flow rate setting because overhead welding sometimes requires adjustment to flow rate and extension.

☐ 3. Place plates in correct joint position and tack weld both ends.

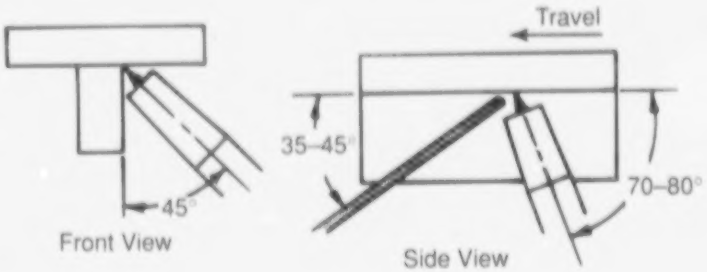
☐ 4. Position plate in accordance with specifications.

☐ 5. Move torch so that nozzle rests on base metal with electrode about 1/8" off base metal.

☐ 6. Lower welding hood and depress foot control until the arc jumps the gap and is established.

☐ 7. Correct electrode angle the moment the arc is established.

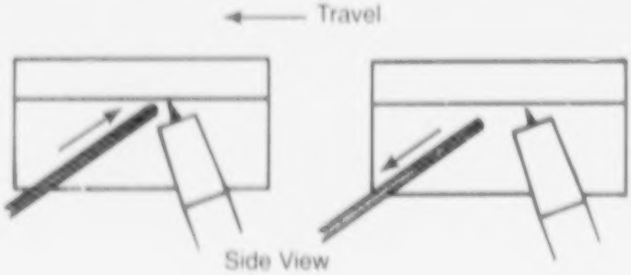
Figure 2



☐ 8. Preheat the starting point until a small molten puddle is formed.

☐ 9. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.

Figure 3



☐ 10. Withdraw filler rod about ½" from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 11. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 12. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

☐ 13. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 14. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 15. Have your instructor check your work.

☐ 16. Continue making passes as directed by your instructor.

☐ 17. Visually inspect each pass and have your instructor check your work.

☐ 18. Repeat procedure for other side of joint, if required and have your instructor check your work.

☐ 19. Shut down equipment as previously outlined.

☐ 20. Check in tools and materials and clean area.

Evaluator's Comments: ______________________________

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Objective 41

Job Sheet 17—Set Up and Shut Down GTAW Equipment for Welding Aluminum

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Setup and machine settings	______
• Flow meter setting	______
• Coolant system check	______
• Tungsten electrode preparation	______
• Shut down safely	______

Basic Skills

Reading   Critical Thinking   Technology

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- GTAW machine with accessories
- Shielding gas as selected by instructor
- Tungsten electrode as selected by instructor
- Coolant
- Brass ground clamp
- Safety clothing and safety glasses

Procedure

☐ 1. Set up power supply.

☐ 2. Set current range selector according to metal thickness.

☐ 3. Set current switch to AC.

☐ 4. Set weld control switch to GTAW.

☐ 5. Set high frequency switch to CONTINUOUS position.

☐ 6. Set control for soft start to avoid burn through on thin metal.

☐ 7. Set remote control switch for contactor or amperage control to either REMOTE or PANEL depending on machine accessories.

☐ 8. Set post flow timer according to electrode size.

☐ 9. Turn on cylinder valve and adjust flow meter regulator to rate of flow recommended for electrode.

☐ 10. Check for proper and complete circulation in the cooling system and verify that there are no leaks.

☐ 11. Select correct size collet and gas nozzle according to electrode size.

☐ 12. Prepare the tungsten electrode with a ball tip. (See Job Sheet 19.)

☐ 13. Adjust the electrode extension to no more than 1/8″.

☐ 14. Connect ground clamp to base metal.

☐ 15. Switch machine on.

☐ 16. Have your instructor check results of your setup procedure.

☐ 17. Prepare for shutdown.

☐ 18. Close gas cylinder valve.

☐ 19. Depress foot control to bleed gas line.

☐ 20. Shut off flow meter regulator.

☐ 21. Turn off cooling system.

☐ 22. Turn off power switch.

☐ 23. Remove electrode from torch and return to proper storage.

☐ 24. Remove collet and gas nozzle and return to proper storage.

☐ 25. Disconnect ground clamp.

☐ 26. Roll cables up neatly and clean up workstation.

Evaluator's Comments: ______________________________

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Objective 42

Job Sheet 18—Prepare Aluminum for GTAW

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Scale removal	______
• Edge preparation	______
• Oxide removal	______
• Cleaning and drying	______

Basic Skills

Reading

Critical Thinking

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Aluminum as selected by instructor
- Portable grinder with stainless steel brush
- Stainless steel brush and file
- Clamps or vise
- Degreasing/deoxidizer solution
- Clean shop rags
- Safety clothing, safety glasses, and face shield

Procedure

☐ 1. Secure workpiece with clamps or vise.

☐ 2. Remove all mill scale, dirt, and paint from all surfaces with portable grinder.

☐ 3. Grind or file edges of joint for specified edge preparation.

☐ 4. Remove surface oxide with stainless steel brush.

☐ 5. Wet a shop rag with cleaning solution and wipe plate to remove any oxide residue.

☐ 6. Wipe plate dry with clean shop rag.

☐ 7. Have your instructor check your work.

☐ 8. Store in a dry place and weld as soon as possible after cleaning.

Evaluator's Comments: ______________________________

____

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Objective 43

Job Sheet 19—Prepare a Tungsten Electrode for Welding Aluminum

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Setup and machine settings	______
• Ball preparation on electrode	______
• Electrode contamination free	______
• Shut down properly	______

Basic Skills

Reading

Critical Thinking

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- GTAW machine with accessories
- Shielding gas as selected by instructor
- Tungsten electrode as selected by instructor
- Thick copper block
- Pliers
- Safety clothing and safety glasses
- Grinding wheel (optional)

Procedure

☐ 1. Set up GTAW equipment as previously outlined.

☐ 2. Switch machine to DCRP (DCEP).

☐ 3. Place electrode in torch.

☐ 4. Position copper block on work table and ground it.

☐ 5. Turn power on.

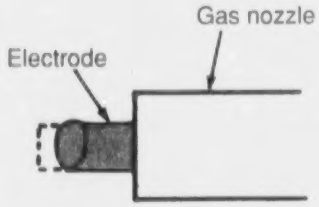
☐ 6. Move torch down with electrode held perpendicular to the copper block until electrode tip is about 1/8″ from the copper block.

☐ 7. Depress foot control to cause arc to jump the gap between electrode tip and copper block.

☐ 8. Allow end of tungsten to turn bright red, but be careful not to contaminate the tungsten by touching the copper block.

☐ 9. Allow electrode tip to form a ball equal to or slightly larger than the diameter of the electrode.

Figure 1



☐ 10. Increase amperage by depressing foot control slightly if the ball is too small.

☐ 11. Continue heating until desired diameter is obtained, then release foot pedal and raise torch and electrode from the block.

> **Caution:** The size of the ball should not exceed 1 1/2 times the electrode diameter or it will become molten and drop off during welding.

☐ 12. Inspect ball for correct diameter and a bright, shiny appearance.

☐ 13. Inspect for discoloration and contamination, and if the tip is purple or black, it indicates post flow of shielding gas is inadequate for the diameter of the electrode and flow should be increased.

☐ 14. Break improper ball off with a pair of pliers and repeat the procedure and inspect.

Note: Larger tungsten electrodes should be tapered before you put a ball on the end. Your instructor may direct you to taper a larger electrode and repeat the procedure for placing a ball on the end.

☐ 15. Have your instructor check your work.

☐ 16. Shut down equipment as previously outlined.

☐ 17. Check in tools and materials and clean area.

Evaluator's Comments: ______________________________

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Objective 44

Job Sheet 20—Strike and Maintain an Arc to Make Stringer Beads on Aluminum Without Filler Metal in the Flat Position

Name ______________________ Attempt Number ______

Date ______________________ Overall Rating ______

Evaluation Criteria	Rating
• Equipment setup and machine adjustments	______
• Electrode preparation	______
• Shielding gas adjustment	______
• Stringer bead quality	______

Basic Skills

Reading

Critical Thinking

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

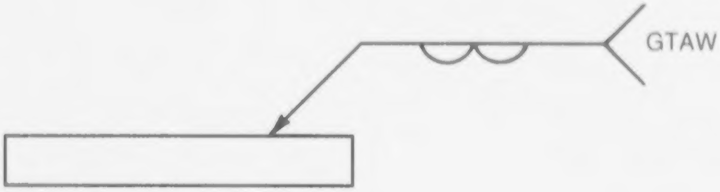
Tools, equipment, and materials

- GTAW machine with accessories
- Aluminum as selected by instructor
- Tungsten electrode to specifications
- Shielding gas to specifications
- Stainless steel wire brush and pliers
- Safety clothing and safety glasses

Specifications

1. Joint design and weld symbol:

Figure 1



2. Filler metal: N/A

3. Tungsten: Per instructor

4. Shielding gas: Ar or He

5. Electrical: AC, high frequency continuous
6. Position: Flat
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: Stainless steel brush
10. Testing: Visual

Procedure

☐ 1. Set up equipment as previously outlined.

☐ 2. Double check electrode extension and shielding gas flow rate.

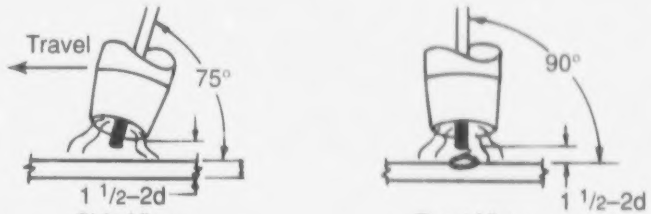
☐ 3. Position plate in accordance with specifications, and hold torch with right hand, if right handed, or opposite if left handed.

☐ 4. Move torch so that nozzle rests on base metal with electrode about 1/8″ off base metal.

☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

☐ 6. Correct electrode angle the moment the arc is established.

Figure 2



Side View

Front View

Courtesy of Lincoln Electric Company.

☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move electrode slowly in the direction of travel, maintaining correct arc length, bead width, and electrode angle.

Note: The bead should penetrate the plate, but should not go through the plate to cause burn through.

☐ 9. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of the weld.

☐ 10. Place torch in a secure, safe place.

☐ 11. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 12. Have your instructor check your work.

☐ 13. Continue making passes as directed by your instructor.

☐ 14. Visually inspect each pass and have your instructor check your work.

☐ 15. Shut down equipment as previously outlined.

☐ 16. Check in tools and materials and clean area.

Evaluator's Comments: ______________________________

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Objective 45

Job Sheet 21—Strike and Maintain an Arc to Make Stringer Beads on Aluminum With Filler Metal in the Flat Position

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
• Equipment setup and machine adjustments	______
• Electrode preparation	______
• Shielding gas adjustment	______
• Filler metal application	______
• Stringer bead quality	______

Basic Skills

Reading Critical Thinking

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

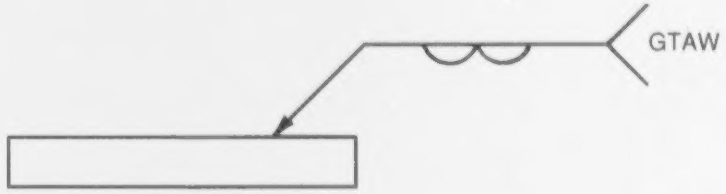
Tools, equipment, and materials

- GTAW machine with accessories
- Aluminum as selected by instructor
- Tungsten electrode as selected by instructor
- Shielding gas to specifications
- Filler metal as selected by instructor
- Stainless steel wire brush and pliers
- Safety clothing and safety glasses

Specifications

1. Joint design and weld symbol:

Figure 1



2. Filler metal: Aluminum per instructor

3. Tungsten: Per instructor

4. Shielding gas: Ar or He
5. Electrical: AC, high frequency continuous
6. Position: Flat
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: Stainless steel brush
10. Testing: Visual

Procedure

☐ 1. Set up equipment as previously outlined.

☐ 2. Double check electrode extension and shielding gas flow rate.

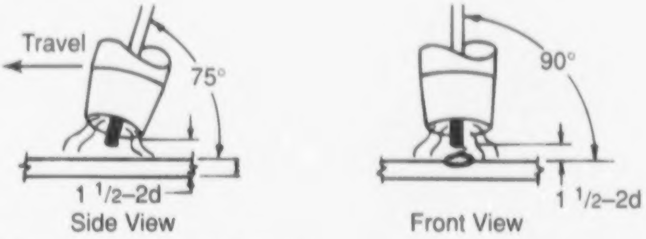
☐ 3. Position plate in accordance with specifications, and hold torch with right hand, if right handed, or opposite if left handed.

☐ 4. Move torch so that nozzle rests on base metal with electrode about $^1/_8$" off base metal.

☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

☐ 6. Correct electrode angle the moment the arc is established.

Figure 2

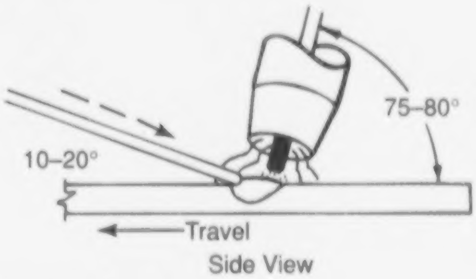


Courtesy of Lincoln Electric Company.

☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.

Figure 3



Courtesy of Lincoln Electric Company.

☐ 9. Withdraw filler rod about 1/2 from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 14. Have your instructor check your work.

☐ 15. Continue making passes as directed by your instructor.

☐ 16. Visually inspect each pass and have your instructor check your work.

☐ 17. Shut down equipment as previously outlined.

☐ 18. Check in tools and materials and clean area.

Evaluator's Comments: ______________________________

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Objective 46

Job Sheet 22—Weld to Specifications a Fillet Weld Lap Joint on Aluminum in the Flat Position

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Equipment setup and safety	______
• Electrode extension	______
• Shielding gas adjustment	______
• Filler metal application	______
• Weld quality	______

Basic Skills

Reading

Critical Thinking

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

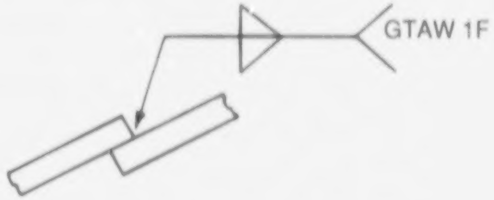
Tools, equipment, and materials

- GTAW machine with accessories
- Aluminum as selected by instructor
- Tungsten electrode as selected by instructor
- Shielding gas to specifications
- Filler metal as selected by instructor
- Stainless steel wire brush and pliers
- Safety clothing and safety glasses

Specifications

1. Joint design and weld symbol:

Figure 1



2. Filler metal: Aluminum per instructor
3. Tungsten: Per instructor
4. Shielding gas: Ar or He

5. Electrical: AC, high frequency continuous
6. Position: 1F
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: Stainless steel brush
10. Testing: Visual

Procedure

☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.

☐ 2. Place plates in correct joint position and tack weld both ends.

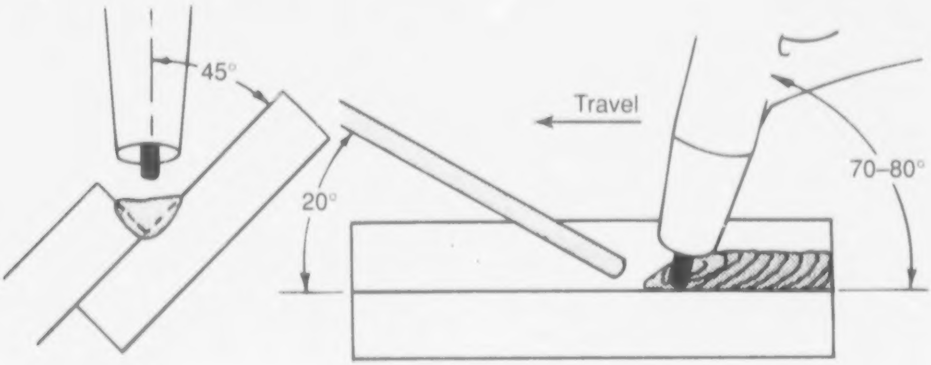
☐ 3. Position plate in accordance with specifications.

☐ 4. Move torch so that nozzle rests on base metal with electrode about 1/8" off base metal.

☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

☐ 6. Correct electrode angle the moment the arc is established.

Figure 2

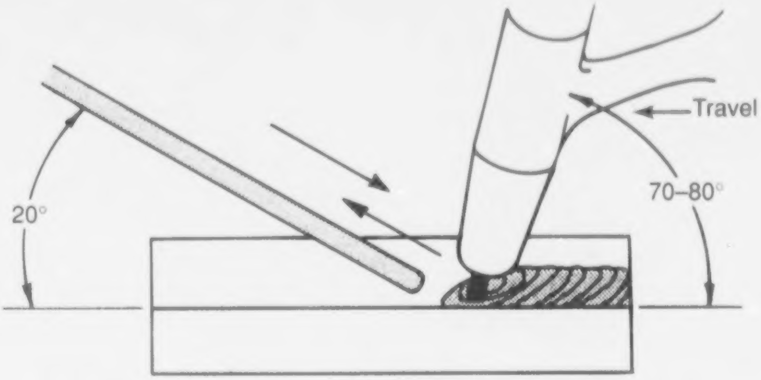


Front View Side View

☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.

Figure 3



Side View

☐ 9. Withdraw filler rod about 1/2 from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 14. Have your instructor check your work.

☐ 15. Continue making passes as directed by your instructor.

☐ 16. Visually inspect each pass and have your instructor check your work.

☐ 17. Repeat procedure for other side of joint, if required and have your instructor check your work.

☐ 18. Shut down equipment as previously outlined.

☐ 19. Check in tools and materials and clean area.

Evaluator's Comments: ______________________________

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____

Objective 47

Job Sheet 23—Weld to Specifications a Fillet Weld T-Joint on Aluminum in the Flat Position

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Equipment setup and safety	______
• Electrode extension	______
• Shielding gas adjustment	______
• Filler metal application	______
• Weld quality	______

Basic Skills

Reading

Critical Thinking

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

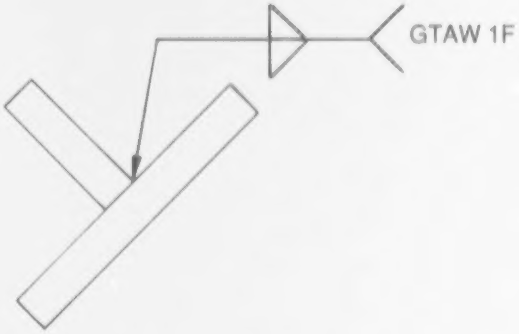
Tools, equipment, and materials

- GTAW machine with accessories
- Aluminum as selected by instructor
- Tungsten electrode as selected by instructor
- Shielding gas to specifications
- Filler metal as selected by instructor
- Stainless steel wire brush and pliers
- Safety clothing and safety glasses

Specifications

1. Joint design and weld symbol:

Figure 1



2. Filler metal: Aluminum per instructor
3. Tungsten: Per instructor
4. Shielding gas: Ar or He
5. Electrical: AC, high frequency set on continuous
6. Position: 1F
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: Stainless steel brush
10. Testing: Visual

Procedure

☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.

☐ 2. Place plates in correct joint position and tack weld both ends.

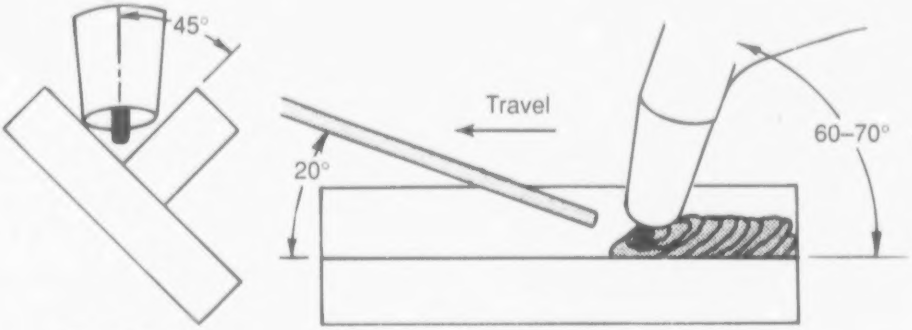
☐ 3. Position plate in accordance with specifications.

☐ 4. Move torch so that nozzle rests on base metal with electrode about $^1/_8$" off base metal.

☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

☐ 6. Correct electrode angle the moment the arc is established.

Figure 2



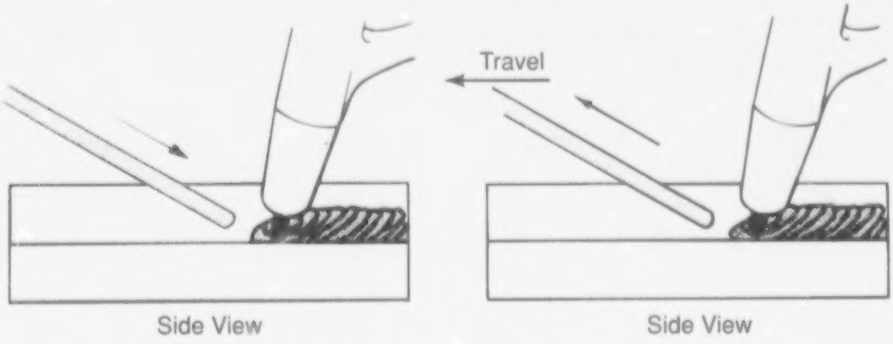
Front View

Side View

☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.

Figure 3



☐ 9. Withdraw filler rod about 1/2 from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

Note: Allow for heat build-up by increasing travel speed or letting up on the foot pedal to decrease amperage.

☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 14. Have your instructor check your work.

☐ 15. Continue making passes as directed by your instructor.

☐ 16. Visually inspect each pass and have your instructor check your work.

☐ 17. Repeat procedure for other side of joint, if required and have your instructor check your work.

☐ 18. Shut down equipment as previously outlined.

☐ 19. Check in tools and materials and clean area.

Evaluator's Comments: ______________________________

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____

Objective 48

Job Sheet 24—Weld to Specifications a Square-Groove Butt Joint on Aluminum in the Flat Position

Name ______________________ Attempt Number ______

Date ______________________ Overall Rating ______

Evaluation Criteria	Rating
• Equipment setup and safety	______
• Electrode extension	______
• Shielding gas adjustment	______
• Filler metal application	______
• Weld quality	______

Basic Skills

Reading

Critical Thinking

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

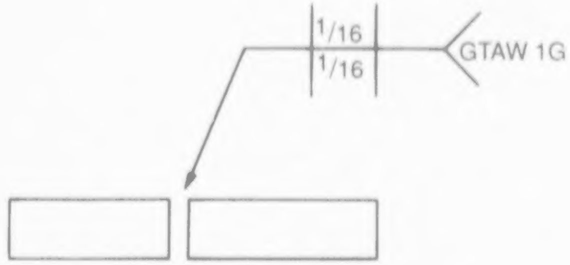
Tools, equipment, and materials

- GTAW machine with accessories
- Grinder with aluminum grinding disk
- Aluminum as selected by instructor
- Tungsten electrode as selected by instructor
- Shielding gas to specifications
- Filler metal as selected by instructor
- 1/16″ gap wire with support plates
- Stainless steel wire brush and pliers
- Safety clothing and safety glasses

Specifications

1. Joint design and weld symbol:

Figure 1



2. Filler metal: Aluminum per instructor
3. Tungsten: Per instructor
4. Shielding gas: Ar or He
5. Electrical: AC, high frequency set on continuous
6. Position: 1G
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: Stainless steel brush
10. Testing: Visual

Procedure

☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.

☐ 2. Place plates in correct joint position and tack weld both ends.

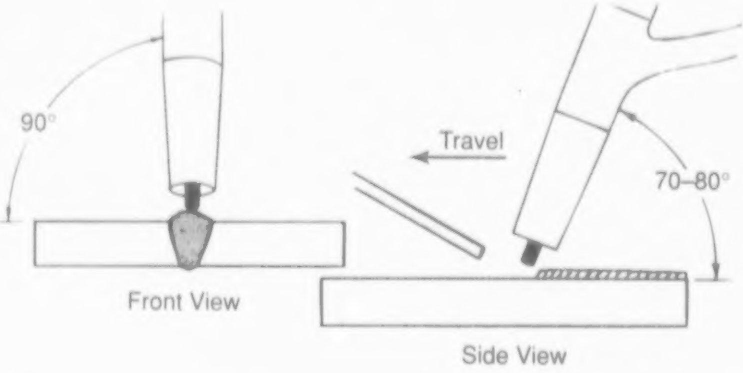
☐ 3. Position plate in accordance with specifications.

☐ 4. Move torch so that nozzle rests on base metal with electrode about $^{1}/_{8}$″ off base metal.

☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

☐ 6. Correct electrode angle the moment the arc is established.

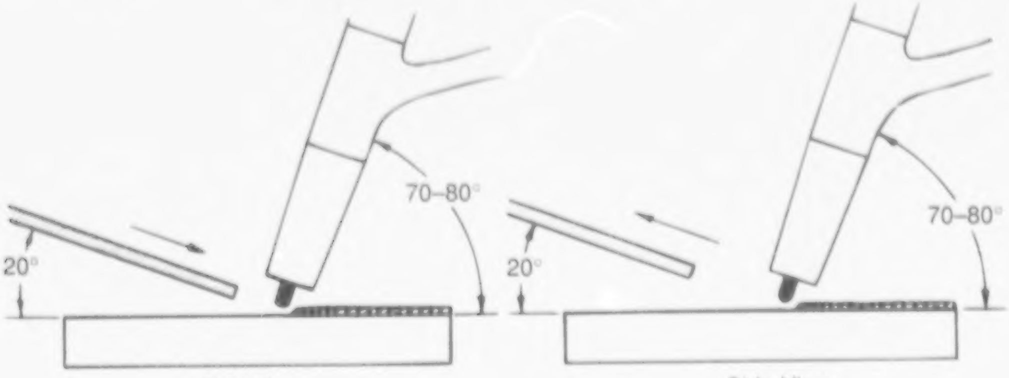
Figure 2



☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.

Figure 3



Side View

Side View

☐ 9. Withdraw filler rod about $^{1}/_{2}$ from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

Note: Allow for heat build-up by increasing travel speed or letting up on the foot pedal to decrease amperage.

☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 14. Have your instructor check your work.

☐ 15. Continue making passes as directed by your instructor.

☐ 16. Visually inspect each pass and have your instructor check your work.

☐ 17. Grind out root side of joint prior to welding other side.

☐ 18. Weld other side of joint, if directed, and have your instructor check your work.

☐ 19. Shut down equipment as previously outlined.

☐ 20. Check in tools and materials and clean area.

Evaluator's Comments: ______________________________

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____

Objective 49

Job Sheet 25—Weld to Specifications a Fillet Weld Lap Joint on Aluminum in the Horizontal Position

Name ____________________ Attempt Number ________

Date ____________________ Overall Rating ________

Evaluation Criteria	Rating
• Equipment setup and safety	______
• Electrode extension	______
• Shielding gas adjustment	______
• Filler metal application	______
• Weld quality	______

Basic Skills

Reading

Critical Thinking

Technology

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

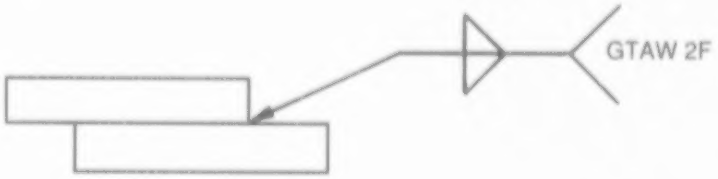
Tools, equipment, and materials

- GTAW machine with accessories
- Aluminum as selected by instructor
- Tungsten electrode as selected by instructor
- Shielding gas to specifications
- Filler metal as selected by instructor
- Stainless steel wire brush and pliers
- Safety clothing and safety glasses

Specifications

1. Joint design and weld symbol:

   Figure 1



2. Filler metal: Aluminum per instructor
3. Tungsten: Per instructor

4. Shielding gas: Ar or He
5. Electrical: AC, high frequency set on continuous
6. Position: 2F
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: Stainless steel brush
10. Testing: Visual

Procedure

☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.

☐ 2. Place plates in correct joint position and tack weld both ends.

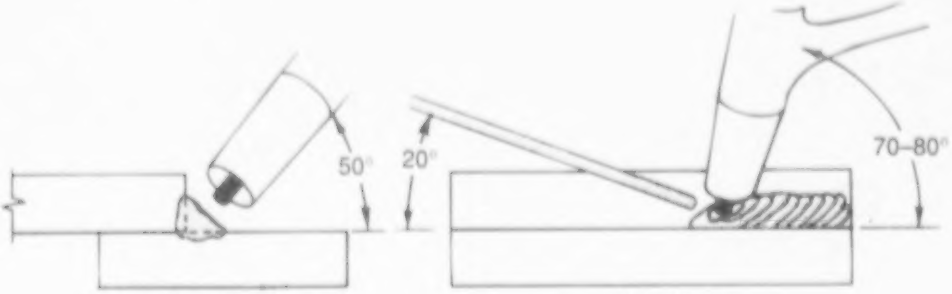
☐ 3. Position plate in accordance with specifications.

☐ 4. Move torch so that nozzle rests on base metal with electrode about 1/8" off base metal.

☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

☐ 6. Correct electrode angle the moment the arc is established.

Figure 2

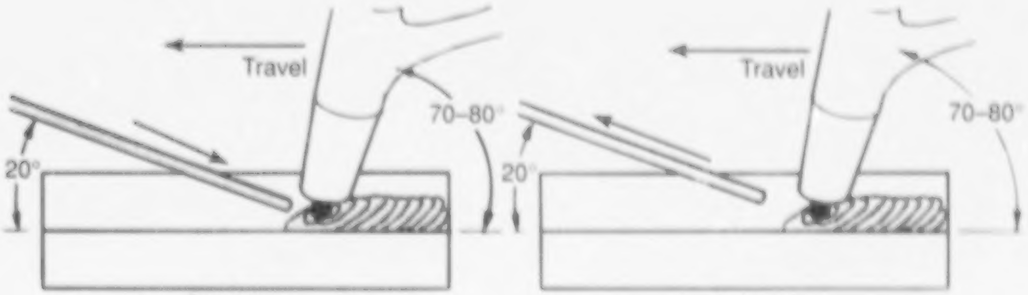


Front View Side View

☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.

Figure 3



Side View Side View

☐ 9. Withdraw filler rod about 1/2 from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

Note: Allow for heat build-up by increasing travel speed or letting up on the foot pedal to decrease amperage.

☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 14. Have your instructor check your work.

☐ 15. Continue making passes as directed by your instructor.

☐ 16. Visually inspect each pass and have your instructor check your work.

☐ 17. Repeat procedure for other side of joint, if required and have your instructor check your work.

☐ 18. Shut down equipment as previously outlined.

☐ 19. Check in tools and materials and clean area.

Evaluator's Comments: ______________________________

____

____

Objective 50

Job Sheet 26—Weld to Specifications a Fillet Weld T-Joint on Aluminum in the Horizontal Position

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Equipment setup and safety	______
• Electrode extension	______
• Shielding gas adjustment	______
• Filler metal application	______
• Weld quality	______

Basic Skills

Reading Critical Thinking Technology

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

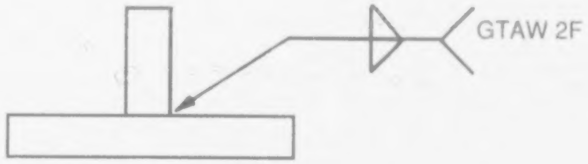
Tools, equipment, and materials

- GTAW machine with accessories
- Aluminum as selected by instructor
- Tungsten electrode as selected by instructor
- Shielding gas to specifications
- Filler metal as selected by instructor
- Stainless steel wire brush and pliers
- Safety clothing and safety glasses

Specifications

1. Joint design and weld symbol:

Figure 1



2. Filler metal: Aluminum per instructor

3. Tungsten: Per instructor

4. Shielding gas: Ar or He
5. Electrical: AC, high frequency set on continuous
6. Position: 2F
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: Stainless steel brush
10. Testing: Visual

Procedure

☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.

☐ 2. Place plates in correct joint position and tack weld both ends.

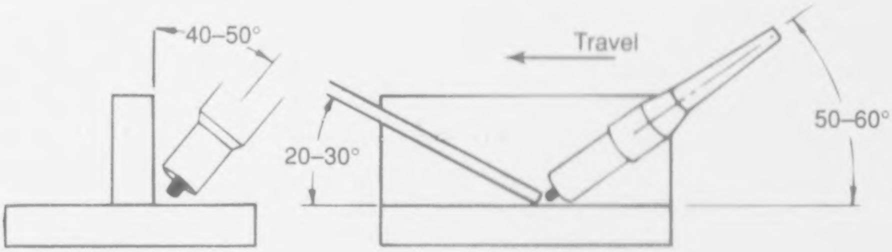
☐ 3. Position plate in accordance with specifications.

☐ 4. Move torch so that nozzle rests on base metal with electrode about $^{1}/_{8}$" off base metal.

☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

☐ 6. Correct electrode angle the moment the arc is established.

Figure 2

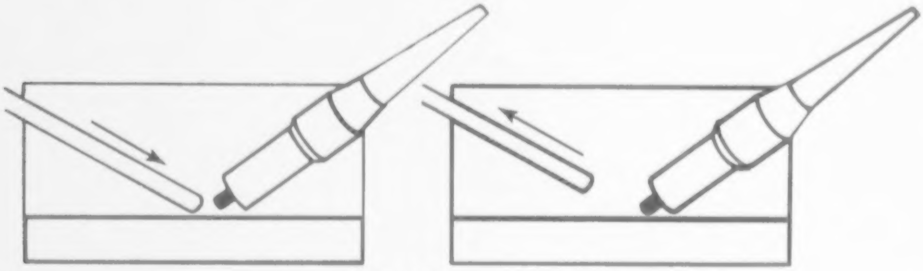


Front View Side View

☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.

Figure 3



Side View

☐ 9. Withdraw filler rod about 1/2 from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

Note: Allow for heat build-up by increasing travel speed or letting up on the foot pedal to decrease amperage.

☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 14. Have your instructor check your work.

☐ 15. Continue making passes as directed by your instructor.

☐ 16. Visually inspect each pass and have your instructor check your work.

☐ 17. Repeat procedure for other side of joint, if required and have your instructor check your work.

☐ 18. Shut down equipment as previously outlined.

☐ 19. Check in tools and materials and clean area.

Evaluator's Comments: ______________________________

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273

Objective 51

Job Sheet 27—Weld to Specifications a Fillet Weld Lap Joint on Aluminum in the Vertical Position

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Equipment setup and safety	______
• Electrode extension	______
• Shielding gas adjustment	______
• Filler metal application	______
• Weld quality	______

Basic Skills

Reading Critical Thinking Technology

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

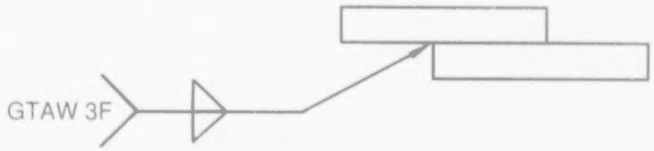
Tools, equipment, and materials

- GTAW machine with accessories
- Aluminum as selected by instructor
- Tungsten electrode as selected by instructor
- Shielding gas to specifications
- Filler metal as selected by instructor
- Stainless steel wire brush and pliers
- Safety clothing and safety glasses

Specifications

1. Joint design and weld symbol:

Figure 1



Top View

2. Filler metal: Aluminum per instructor

3. Tungsten: Per instructor

4. Shielding gas: Ar or He
5. Electrical: AC, high frequency set on continuous
6. Position: 3F
7. Direction of welding: Vertical up
8. Technique: Steady forward motion
9. Cleaning: Stainless steel brush
10. Testing: Visual

Procedure

☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.

☐ 2. Place plates in correct joint position and tack weld both ends.

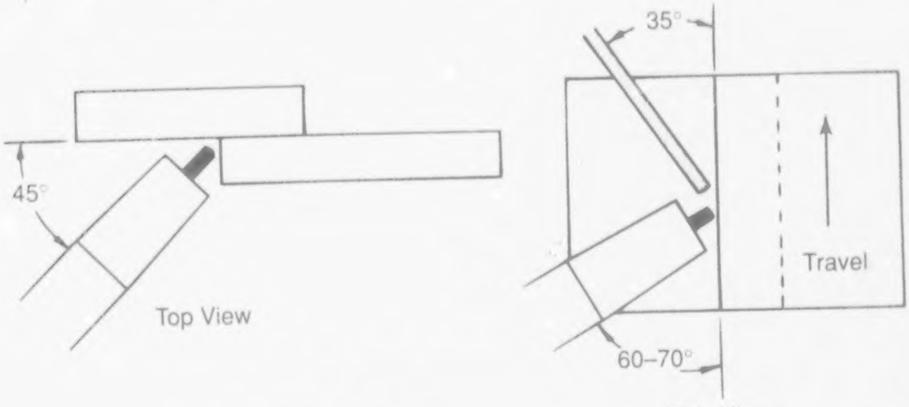
☐ 3. Position plate in accordance with specifications.

☐ 4. Move torch so that nozzle rests on base metal with electrode about 1/8″ off base metal.

☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

☐ 6. Correct electrode angle the moment the arc is established.

Figure 2



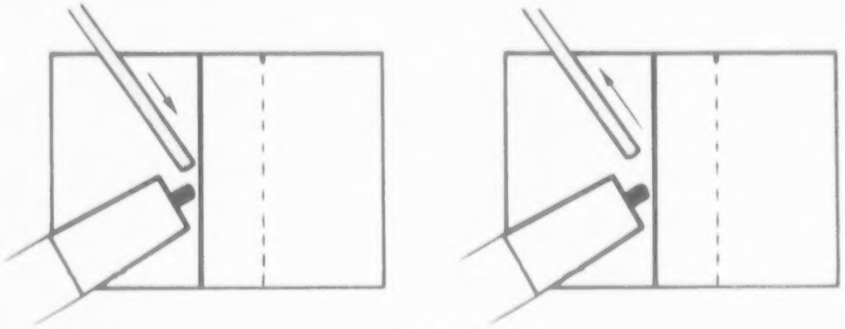
Top View

Side View

☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.

Figure 3



Side View

☐ 9. Withdraw filler rod about 1/2 from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

Note: Allow for heat build-up by increasing travel speed or letting up on the foot pedal to decrease amperage.

☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 14. Have your instructor check your work.

☐ 15. Continue making passes as directed by your instructor.

☐ 16. Visually inspect each pass and have your instructor check your work.

☐ 17. Repeat procedure for other side of joint, if required and have your instructor check your work.

☐ 18. Shut down equipment as previously outlined.

☐ 19. Check in tools and materials and clean area.

Evaluator's Comments: ______________________________

Objective 52

Job Sheet 28—Weld to Specifications a Fillet Weld T-Joint on Aluminum in the Vertical Position

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Equipment setup and safety	____
• Electrode extension	____
• Shielding gas adjustment	____
• Filler metal application	____
• Weld quality	____

Basic Skills

Reading Critical Thinking Technology

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

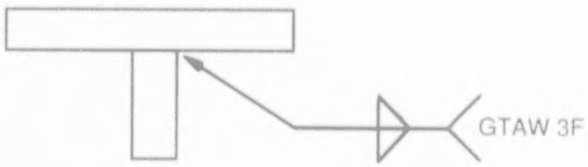
Tools, equipment, and materials

- GTAW machine with accessories
- Aluminum as selected by instructor
- Tungsten electrode as selected by instructor
- Shielding gas to specifications
- Filler metal as selected by instructor
- Stainless steel wire brush and pliers
- Safety clothing and safety glasses

Specifications

1. Joint design and weld symbol:

Figure 1



Top View

2. Filler metal: Aluminum per instructor

3. Tungsten: Per instructor

4. Shielding gas: Ar or He
5. Electrical: AC, high frequency set on continuous
6. Position: 3F
7. Direction of welding: Vertical up
8. Technique: Steady forward motion
9. Cleaning: Stainless steel brush
10. Testing: Visual

Procedure

☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.

☐ 2. Place plates in correct joint position and tack weld both ends.

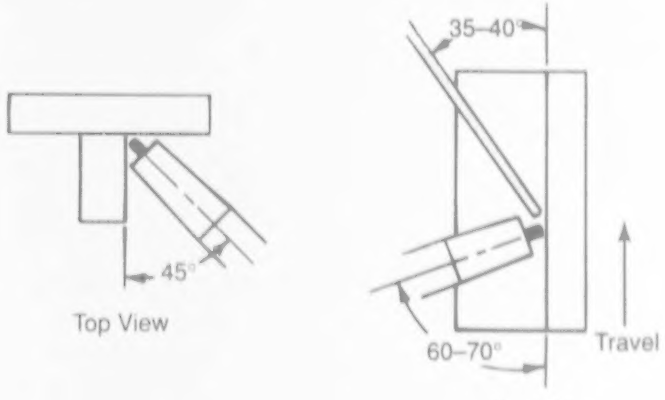
☐ 3. Position plate in accordance with specifications.

☐ 4. Move torch so that nozzle rests on base metal with electrode about 1/8" off base metal.

☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

☐ 6. Correct electrode angle the moment the arc is established.

Figure 2



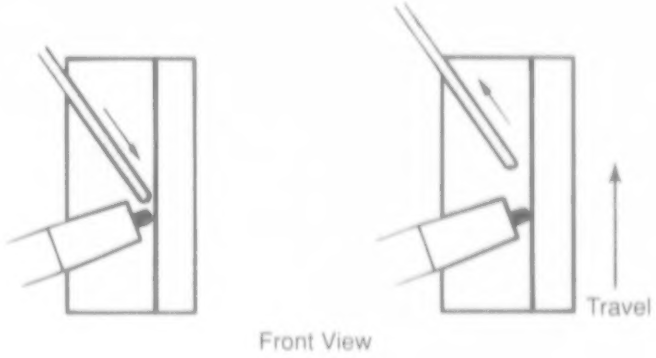
Top View

Front View

☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.

Figure 3



☐ 9. Withdraw filler rod about 1/2 from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

Note: Allow for heat build-up by increasing travel speed or letting up on the foot pedal to decrease amperage.

☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 14. Have your instructor check your work.

☐ 15. Continue making passes as directed by your instructor.

☐ 16. Visually inspect each pass and have your instructor check your work.

☐ 17. Repeat procedure for other side of joint, if required and have your instructor check your work.

☐ 18. Shut down equipment as previously outlined.

☐ 19. Check in tools and materials and clean area.

Evaluator's Comments: ______________________________

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Objective 53

Job Sheet 29—Weld to Specifications a Square-Groove Butt Joint on Aluminum in the Vertical Position

Name ____________________ Attempt Number ________

Date ____________________ Overall Rating ________

Evaluation Criteria	Rating
• Equipment setup and safety	________
• Electrode extension	________
• Shielding gas adjustment	________
• Filler metal application	________
• Weld quality	________

Basic Skills

Reading Critical Thinking Technology

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

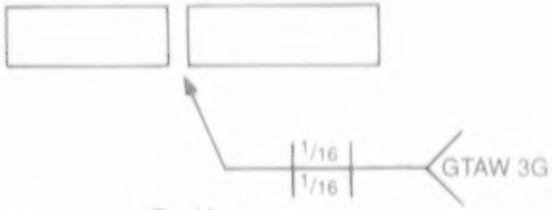
Tools, equipment, and materials

- GTAW machine with accessories
- Grinder with aluminum grinding disk
- Aluminum as selected by instructor
- Tungsten electrode as selected by instructor
- Shielding gas to specifications
- Filler metal as selected by instructor
- Stainless steel wire brush and pliers
- $^1/_{16}$" gap wire
- Safety clothing and safety glasses

Specifications

1. Joint design and weld symbol:

Figure 1



Top View

2. Filler metal: Aluminum per instructor

3. Tungsten: Per instructor
4. Shielding gas: Ar or He
5. Electrical: AC, high frequency set on continuous
6. Position: 3G
7. Direction of welding: Vertical up
8. Technique: Steady forward motion
9. Cleaning: Stainless steel brush
10. Testing: Visual

Procedure

☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.

☐ 2. Place plates in correct joint position and tack weld both ends.

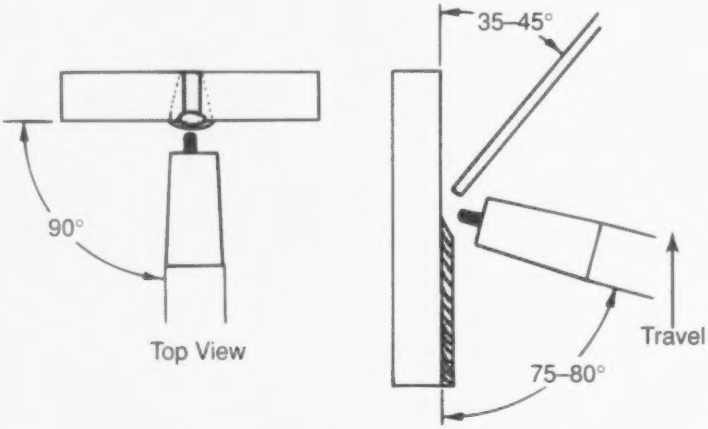
☐ 3. Position plate in accordance with specifications.

☐ 4. Move torch so that nozzle rests on base metal with electrode about $^{1}/_{8}$″ off base metal.

☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

☐ 6. Correct electrode angle the moment the arc is established.

Figure 2



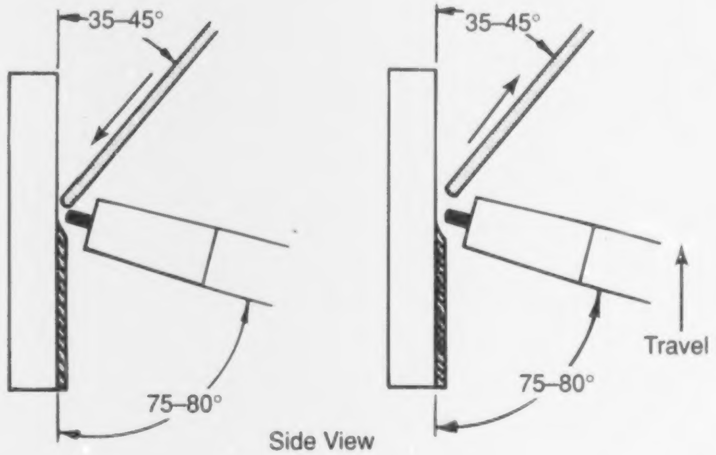
Top View

Side View

☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.

Figure 3



Side View

☐ 9. Withdraw filler rod about 1/2 from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

Note: Allow for heat build-up by increasing travel speed or letting up on the foot pedal to decrease amperage.

☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 14. Have your instructor check your work.

☐ 15. Continue making passes as directed by your instructor.

☐ 16. Visually inspect each pass and have your instructor check your work.

☐ 17. Grind out root side of joint prior to welding other side.

☐ 18. Repeat procedure for other side of joint, if required and have your instructor check your work.

☐ 19. Shut down equipment as previously outlined.

☐ 20. Check in tools and materials and clean area.

Evaluator's Comments: ____

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Objective 54

Job Sheet 30—Weld to Specifications a Fillet Weld Lap Joint on Aluminum in the Overhead Position

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Equipment setup and safety	______
• Electrode extension	______
• Shielding gas adjustment	______
• Filler metal application	______
• Weld quality	______

Basic Skills

Reading
Critical Thinking
Technology

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

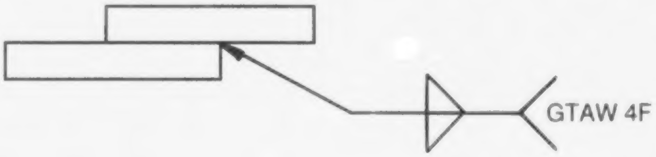
Tools, equipment, and materials

- GTAW machine with accessories
- Aluminum as selected by instructor
- Tungsten electrode as selected by instructor
- Shielding gas to specifications
- Filler metal as selected by instructor
- Stainless steel wire brush and pliers
- Safety clothing and safety glasses

Specifications

1. Joint design and weld symbol:

Figure 1



2. Filler metal: Aluminum per instructor

3. Tungsten: Per instructor

4. Shielding gas: Ar or He
5. Electrical: AC, high frequency set on continuous
6. Position: 4F
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: Stainless steel brush
10. Testing: Visual

Procedure

☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.

☐ 2. Check with your instructor about electrode extension and flow rate setting because overhead welding sometimes requires adjustment to flow rate and extension.

☐ 3. Place plates in correct joint position and tack weld both ends.

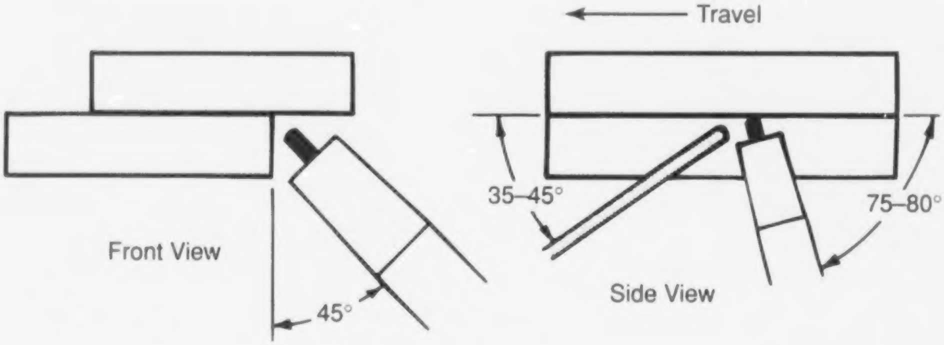
☐ 4. Position plate in accordance with specifications.

☐ 5. Move torch so that nozzle rests on base metal with electrode about 1/8" off base metal.

☐ 6. Lower welding hood and depress foot control until the arc jumps the gap and is established.

☐ 7. Correct electrode angle the moment the arc is established.

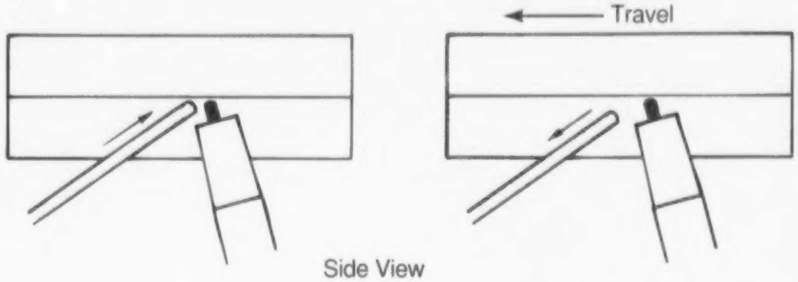
Figure 2



☐ 8. Preheat the starting point until a small molten puddle is formed.

☐ 9. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.

Figure 3



Side View

☐ 10. Withdraw filler rod about 1/2 from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 11. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 12. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

☐ 13. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 14. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 15. Have your instructor check your work.

☐ 16. Continue making passes as directed by your instructor.

☐ 17. Visually inspect each pass and have your instructor check your work.

☐ 18. Repeat procedure for other side of joint, if required and have your instructor check your work.

☐ 19. Shut down equipment as previously outlined.

☐ 20. Check in tools and materials and clean area.

Evaluator's Comments: ____________________

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Objective 55

Job Sheet 31—Weld to Specifications a Fillet Weld T-Joint on Aluminum in the Overhead Position

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation Criteria	Rating
• Equipment setup and safety	______
• Electrode extension	______
• Shielding gas adjustment	______
• Filler metal application	______
• Weld quality	______

Basic Skills

Reading Critical Thinking Technology

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

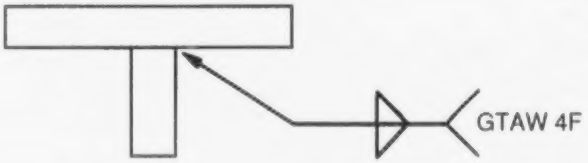
Tools, equipment, and materials

- GTAW machine with accessories
- Aluminum as selected by instructor
- Tungsten electrode as selected by instructor
- Shielding gas to specifications
- Filler metal as selected by instructor
- Stainless steel wire brush and pliers
- Safety clothing and safety glasses

Specifications

1. Joint design and weld symbol:

Figure 1



2. Filler metal: Aluminum per instructor

3. Tungsten: Per instructor

4. Shielding gas: Ar or He

5. Electrical: AC, high frequency set on continuous
6. Position: 4F
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: Stainless steel brush
10. Testing: Visual

Procedure

☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.

☐ 2. Check with your instructor about electrode extension and flow rate setting because overhead welding sometimes requires adjustment to flow rate and extension.

☐ 3. Place plates in correct joint position and tack weld both ends.

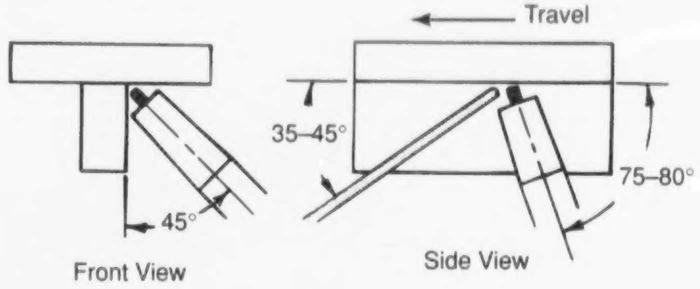
☐ 4. Position plate in accordance with specifications.

☐ 5. Move torch so that nozzle rests on base metal with electrode about $^1/_8$″ off base metal.

☐ 6. Lower welding hood and depress foot control until the arc jumps the gap and is established.

☐ 7. Correct electrode angle the moment the arc is established.

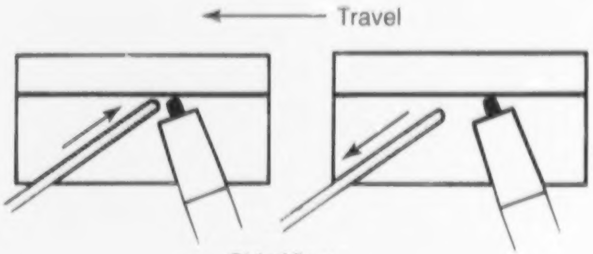
Figure 2



☐ 8. Preheat the starting point until a small molten puddle is formed.

☐ 9. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.

Figure 3



Side View

☐ 10. Withdraw filler rod about $^1/_2$ from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 11. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 12. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

☐ 13. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 14. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 15. Have your instructor check your work.

☐ 16. Continue making passes as directed by your instructor.

☐ 17. Visually inspect each pass and have your instructor check your work.

☐ 18. Repeat procedure for other side of joint, if required and have your instructor check your work.

☐ 19. Shut down equipment as previously outlined.

☐ 20. Check in tools and materials and clean area.

Evaluator's Comments: ______________________________

____

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Objective 23

Job Sheet 1—Prepare a PAC Machine for Operation

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Compressed air supply purge	______
• Air pressure verification	______
• Set up and shut down properly	______

Basic Skills

Reading

Critical Thinking

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- PAC machine with torch and accessories
- Operator's manual for selected PAC machine
- Personal safety clothing and safety glasses

Procedure

☐ 1. Check the workplace for flammable materials, and remove or cover them.

☐ 2. Turn on the compressed air supply.

☐ 3. Locate the compressed air filter on the air line between the air supply and the PAC machine.

☐ 4. Purge excess moisture from the filter by depressing the purge button at the bottom of the filter.

Note: If you're working with a system that has a different type of filter, check the operator's manual for the correct procedure, and if you have to replace a filter, be sure the compressed air supply is turned off.

☐ 5. Turn on the PAC machine power switch.

☐ 6. Set air pressure to manufacturer's specifications.

☐ 7. Press the trigger button on the plasma torch and listen for air flow through the torch.

☐ 8. Watch the air pressure as you press the trigger button; there should be a slight drop in pressure to indicate proper air flow.

☐ 9. Have your instructor check your work.

☐ 10. Turn the power switch off.

☐ 11. Secure the PAC machine and the plasma torch.

Evaluator's Comments: ______________________________

____

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Objective 24

Job Sheet 2—Complete a Contact Cut on Selected Metal

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Workpiece preparation	______
• Workpiece cut alignment	______
• Use of straightedge and clamps	______
• Setup technique	______
• Ground clamp placement	______
• Proper angle to start cut	______
• Cutting technique	______
• Shutdown technique	______

Basic Skills

Reading Critical Thinking Technology

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- PAC machine with torch and accessories
- Welding helmet or goggles with minimum #9 lens shade
- Metal as selected by instructor
- Contact shielding cup for plasma torch
- Straightedge, soapstone, and C-clamps
- Wire brush
- Ear protection, safety clothing, and safety glasses

Procedure

☐ 1. Check the workplace for flammable materials, and remove or cover them.

☐ 2. Put on safety glasses.

☐ 3. Clean all rust and scale from the workpiece with a wire brush.

☐ 4. Measure and mark the cutting line on the workpiece with a straightedge and soapstone.

☐ 5. Place the workpiece on the work table with the edge to be cut extended over the edge of the table, far enough for the plasma stream to clear the work table.

☐ 6. Place the straightedge along the cut line and clamp the straightedge and the workpiece to the work table with the clamps positioned so they will not interfere with the cut.

☐ 7. Clamp the PAC machine ground clamp onto the workpiece or as close to the workpiece as possible.

☐ 8. Set up the PAC machine as previously outlined.

☐ 9. Turn the PAC power switch on; put on your welding goggles or helmet and ear protection.

☐ 10. Position the contact shielding cup so that it contacts the workpiece at a slight angle opposite the direction of travel.

☐ 11. Press the torch trigger button; listen for air flow to start through the plasma torch.

☐ 12. Wait about two seconds for the pilot arc to come on, and immediately move the torch along the cut line.

☐ 13. Use a smooth, continuous motion to move the plasma torch along the straightedge while maintaining the correct torch angle all along the cut.

> **Caution:** Keep your legs and feet out of the way as you finish the cut because the cut portion will fall off.

☐ 14. Complete the cut, release the gun trigger button, and keep the torch in your hand as the arc stops and air continues to flow.

☐ 15. Allow air to flow until it stops to help cool gun components.

☐ 16. Have your instructor check your work.

☐ 17. Turn the power switch off.

☐ 18. Secure the PAC machine and torch.

☐ 19. Clean the area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

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Objective 25

Job Sheet 3—Complete a Stand-Off Cut on Selected Metal

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Workpiece preparation	______
• Cutting line mark	______
• Shield cup selection	______
• Setup technique	______
• Ground clamp placement	______
• Torch angle	______
• Cutting technique	______
• Shutdown technique	______

Basic Skills

Reading Critical Thinking Technology

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- PAC machine with torch and accessories
- Welding helmet or goggles with minimum #9 lens shade
- Metal as selected by instructor
- Stand-off shielding cup or device for plasma torch
- Straightedge, soapstone, and C-clamps
- Wire brush
- Ear protection, safety clothing, and safety glasses

Procedure

☐ 1. Check the workplace for flammable materials, and remove or cover them.

☐ 2. Put on safety glasses.

☐ 3. Clean all rust and scale from the workpiece with a wire brush.

☐ 4. Measure and mark the cutting line on the workpiece with a straightedge and soapstone.

☐ 5. Place the workpiece on the work table with the edge to be cut off extended over the edge of the table, far enough for the plasma stream to clear the work table.

☐ 6. Secure the workpiece with C-clamps.

☐ 7. Clamp the PAC machine ground clamp on the workpiece or as close to the workpiece as possible.

☐ 8. Set up the PAC machine as previously outlined.

☐ 9. Use the proper tool to remove the standard shield cup, and replace it with a stand-off shield cup or stand-off device.

Note: Tighten the cup until it is snug. Don't overtighten. If you're working with a system that recommends hand tightening, don't use a tool.

☐ 10. Position the plasma torch so that it touches the workpiece and is aligned vertically at a 90° angle with the workpiece.

☐ 11. Maintain the 90° angle while you press the torch trigger switch; listen for air flow to start through the plasma torch.

☐ 12. Wait about two seconds for the pilot arc to come on, and immediately move the torch along the cut line.

☐ 13. Use a smooth, continuous motion to move the plasma torch along the cut line while maintaining the 90° torch angle all along the cut line.

☐ 14. Complete the cut, release the trigger switch, and keep the torch in your hand as the arc stops and air continues to flow.

☐ 15. Allow air to flow until it stops; this helps cool torch components.

☐ 16. Have your instructor check your work.

☐ 17. Turn off the power switch.

☐ 18. Secure the PAC machine and torch.

☐ 19. Clean the area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

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Objective 26

Job Sheet 4—Gouge Mild Steel Plate With a PAC Unit

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Workpiece preparation	______
• Gouging line mark	______
• Gouging cup selection	______
• Setup technique	______
• Ground clamp placement	______
• Gouging angle and technique	______
• Shutdown technique	______

Basic Skills

Reading Critical Thinking Technology

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- PAC machine with torch and accessories
- Welding helmet or goggles with minimum #9 lens shade
- Metal as selected by instructor
- Gouging nozzle for plasma torch
- Straightedge, soapstone, and C-clamps
- Wire brush
- Ear protection, safety clothing, and safety glasses

Procedure

☐ 1. Check the workplace for flammable materials, and remove or cover them.

☐ 2. Put on safety glasses.

☐ 3. Clean all rust and scale from the workpiece with a wire brush.

☐ 4. Measure and mark the gouging line on the workpiece with a straightedge and soapstone.

☐ 5. Place the workpiece on the work table so that sparks from gouging will blow into a safe area.

☐ 6. Secure the workpiece with C-clamps.

☐ 7. Clamp the PAC machine ground clamp on the workpiece or as close to the workpiece as possible.

☐ 8. Set up the PAC machine as previously outlined.

☐ 9. Use the proper tool to remove the shield cup and nozzle, and replace the nozzle with a gouging nozzle.

Note: Tighten the cup until it is snug. Don't overtighten. If you're working with a system that recommends hand tightening, don't use a tool.

☐ 10. Position the shield cup so that it contacts the workpiece at an angle approximately 30° from the horizontal.

☐ 11. Press the torch trigger switch while you listen for air flow to start through the plasma torch.

☐ 12. Wait about two seconds for the pilot arc to come on, and immediately move the torch along the gouge line.

☐ 13. Use a smooth, continuous motion to push the torch along the gouge line; you may need to adjust the torch angle up slightly for a deeper gouge or adjust the angle down slightly for a more shallow gouge, or adjust travel speed.

☐ 14. Complete the gouge, release the trigger switch, and keep the torch in your hand as the arc stops and air continues to flow.

☐ 15. Allow air to flow until it stops; this helps cool torch components.

☐ 16. Have your instructor check your work.

Note: Your instructor may instruct you to experiment with torch angles and travel speed. The instructor may also instruct you to experiment with a weaving technique to broaden the width of the gouge.

☐ 17. Turn off the power switch.

☐ 18. Secure the PAC machine and torch.

☐ 19. Clean the area and return tools and materials to proper storage.

Evaluator's Comments: ____________________

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